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ADDITIONAL RHIZANGIID CORALS FROM THE WANGANUI SERIES

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(Received for publication, 17 August 1959)

Summary

Two additional species of Rhizangiid corals are recorded from the Wanganui Basin. *Culicia rubeola* (Quoy and Gaimard) is also represented in the modern fauna and is discussed in relation to depth distribution of the Wanganui faunas and possible occurrence of derived coral specimens in the Cook Strait area. *Oulangia radames* n. sp. is reported for the first time from New Zealand. Its appearance in Tongaporutuan sediments is the earliest record of the genus. Some aspects of the ecology of its occurrence are discussed.

INTRODUCTION

Coral faunas of the Wanganui Series are remarkable for the paucity of both individuals and variety of types. The rich coral faunas of the Southland Series were apparently unable to survive the rigours of the later Tertiary and, with the exception of a relatively few species, became extinct in New Zealand. During Wanganui time those species which survived must have been living in waters nearer the shelf margin and may be preserved in sediments now undergoing submarine erosion, but are largely absent from sediments deposited in shallower water now exposed on land. Only two species, *Flabellum campanulatum* Holdsworth and *Balanophyllia zelandiae* Squires are sufficiently distributed to be termed characteristic of Wanganui sediments, while *Caryophyllia coronatus* Tenison-Woods, *Lophelia parvisecta* (Tenison-Woods) and *Oculina virgosa* Squires are rather irregular in their occurrence. All these species are found in deposits laid down in median to deep shelf

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environments and are confined to the eastern side of the North Island, with the exception of *Flabellum campanulatum*. *Flabellum campanulatum* occurs in the Kanieri region and at restricted localities in the Wanganui Basin. Occurrences of *Flabellum* and *Balanophyllia* in presumed shallow water deposits of the Chatham Islands are not considered here because of the strong possibility of a different thermal regime pertaining there.

A single species referable to *Astrangia* (*Coenangia*) sp., recorded from Castlecliff (Squires, 1958, p. 37) is significant, for this genus and its relatives in the Family Rhizangiidae are characteristically found in the littoral zone of temperate and tropical regions. The interesting implications, apart from the extension of the geographic range of the subgenus, otherwise confined to the Atlantic and Pacific coasts of North and Central America, include the possibility of a greater rhizangiid fauna being recorded from the shallow seas of the Wanganui Basin. Examinations of the collections of the N.Z. Geological Survey and further collecting have indeed added to the fauna and have also demonstrated some interesting examples of local ecologies.

Two additional specimens of rhizangiid corals are now known from the Wanganui Series: *Culicia rubeola* (Quoy and Gaimard), also known from the modern fauna; and *Oulangia radames* n. sp. which has been collected from the Waitotaran (Upper Pliocene) and Tongaporutuan (Upper Miocene). The former species is known from a single specimen from the Nukumaruan (Lower Pleistocene) and many occurrences in modern faunas. The latter, *Oulangia radames* n. sp., has in New Zealand its earliest record both as a genus and as a species; it was previously known generically from the Philippine Islands, Gulf of Panama, and the Pleistocene and Recent of Japan.

The occurrence of *Oulangia radames* n. sp. in the Waitotaran is of interest because it displays close inter-relationships between species. In the lower Waitotaran oulangiid corals are associated with "beds" of *Atrina* sp. The *Atrina* shells are found more or less in growth position with the apex of the shell imbedded in the substratum beneath a bedding plane, often with the upper portion of the shell broken off and lying along or inclined to the bedding plane, as though the result of compaction of the overlying sediments. This association is believed to have developed in very shallow waters on a mud substratum (Powell, 1937) during a period of slow deposition. A mud flat environment is an unlikely place to find corals of this type for they require some hard substratum on which to settle and grow, provided in this case by shells of *Atrina*. Many specimens of *Ostrea* cf. *O. sinuata* are also found attached to *Atrina*, for most oysters also require a solid substrate for the settlement of the spat. These oysters develop an attachment area consisting of a solid pad of shell, which solidly adheres to its substrate, of about the same area as one of the valves, that is, up to 3 in. in longest dimension, and often $\frac{3}{4}$ in. thick. The oysters must have grown much more rapidly than the smaller corals (average diameter about $\frac{1}{2}$ in.) for they were more successful in the competition for available space on some *Atrina* valves. One may assume that many other forms not readily preserved such as algae, sponges and anemones were also present.

In many instances *Oulangia radames* n. sp. was overwhelmed by the growth of the oysters and the coralla were incorporated into the basal attachment pad of the oysters (fig. 1). The struggle was not a passive one, for the

coralla of *Oulangia* imbedded in *Ostrea* are usually taller in proportion to diameter than "free" specimens and some of them display curvature of the corallum not found in free forms. One specimen collected shows the "struggle" as it was terminated by the burial of the participants (fig. 4). Several specimens are distorted but are not associated with *Ostrea* or other calcareous materials and are presumed to have been surrounded or imbedded in some unpreserved soft tissues.

Associations of this type are not uncommon in shallow water, mud-bottom conditions within the known depth range of *Oulangia*, intertidal to 15 m. The species should be looked for in lithotopes such as shell beds or other deposits representing bottom conditions that offered a firm substrate.

Although *Culicia rubeola* (Quoy and Gaimard) is also presumed to occur in shallow waters, its potential depth range is much greater than that of *Oulangia*. The species has been recorded from waters to 60 fm in depth from the seas about North Island. This compares well with the only known fossil occurrence of the species, in the Nukumaru Group, for which Fleming (1953) suggested a depositional depth range in the upper neritic zone.

Another occurrence of *Culicia rubeola* is from a depth of 25 fm in the South Taranaki Bight (N.Z. Geol. Surv. Coll.). The specimen is worn, and the calices were filled solidly with a blue clay. In association with this specimen and from a large number of other samples from the South Taranaki Bight region are specimens of *Flabellum campanulatum*, which in every way (including morphological characters and state of preservation) resemble specimens taken from Wanganui outcrops. Derived fossils are not unknown from the Cook strait region (Fleming, 1951; Pantin, 1957; Vella, 1957) but such occurrences are generally more south-easterly, in the region of active scour, while the specimens under consideration are from a point further to the north.

The rarity of *Flabellum campanulatum* from sediments exposed in the Wanganui Basin (as well as the total absence of *Balanophyllia zelandiae*, *Carophyllia coronatus* et al) poses a problem in interpretation. One might postulate a separation of the faunas of east and west North Island through Wanganui time, with perhaps interchange of shallow water species during the Waitotaran. More real, however, is the possibility that these faunas are apparently absent because of the lack of exposed deposits representing the appropriate depths for the faunas. The depth range for modern *Flabellum campanulatum* is approximately 20 to 100 fm; the occurrences of the species in the Wanganui Basin are in the deeper water facies, for example, the Tainui Shell Bed (cf. Fleming, 1953). Extrapolating from the data given by Fleming (1953), one might postulate the occurrence of this depth range well to the south, in South Taranaki Bight (in the broad sense).

In a similar fashion, the total absence of coral faunas from the Hawera Series should be attributed either to cooling waters and the withdrawal of the fauna to another region, or more probably to the defective nature of the record. It is presumed, but not demonstrable, that collectable Hawera marine deposits are generally of a facies too shallow for the majority of corals. This then presents a problem for the compiler of range charts. Does one indicate the complete absence, leaving the alternative choices open, or may one legitimately suggest that the faunas were present but have not been collected by reason of inaccessibility?

Dead coralla of *Flabellum campanulatum* are abundantly recorded from marine dredgings both in the Taranaki Bight and in regions of active scour (Fleming, 1951; Reed and Leopard, 1954) such as the M/V "Alert" Bottom Sample Stations 166, 173, 180 (Dominion Museum Coll.). This suggests that the species was present in rocks of unknown age but presumed to be Wanganui or Hawera Series, in some abundance and is being brought to the surface by past or present erosional activity.

The addition of the Rhizangiidae to the known Wanganui Series fauna indicates that all general habitats were occupied by corals during this time. The rhizangiids occupied the shallow waters of the shelf, while in succeeding deeper zones were to be found *Flabellum campanulatum*, *Balanophyllia zelandiae* and *Carophyllia coronatus*.

Modern rhizangiid corals are typically found in the littoral regions of temperate and tropical seas. Thermal ranges for the genera concerned are given by Vaughan and Wells (1943, p. 53, 54) as follows: *Culicia* 12° to 27.7°C; *Oulangia* 25° to 26.7°C. The latter is more clearly a subtropical to tropical form while the former is more widely ranging and is also found in the temperate seas of Australia and New Zealand today. Fleming (1944) demonstrated the progressive cooling of the post-Mid-Miocene seas and suggested a minimal temperature during the Nukumaruan while post-Nukumaruan temperatures were not appreciably lower than those prevailing today. All faunal evidence, including that of the corals (Squires, 1958, p. 23) suggests a gradual depletion of the faunas from the Clifdenian onwards which is usually attributed to declining temperatures. The appearance of *Oulangia* in the Tongaporutuan and lower Waitotaran, in view of its present temperature range, is somewhat anomalous and could be suggested as evidence for warm late Miocene-Pliocene waters. An alternative suggestion is that the present known thermal range of *Oulangia* is more restricted than that of its past representatives.

This study was made possible by a Fulbright Research Fellowship for the further consideration of New Zealand Tertiary coral faunas. It is a pleasure to acknowledge the assistance of Dr C. A. Fleming and Mr Ian Speden both in collecting and in conversations regarding the associations of the rhizangiid corals. Miss Dawn Rodley, Victoria University of Wellington, generously contributed the specimen she collected from the Tongaporutuan.

DESCRIPTION: Corallum solitary, reptoid, corallites cylindrical and low. Wall costate but with some shreds of epitheca. Costae broad, rounded, separated by sharp, deep, furrows which become obsolete basally. Calice broadly open, not deep. Septa in excess of four cycles (48+). Septa of first and second cycles very slightly exsert, rounding gently except for one or two large dentations near the columella. Second cycle septa similar to those of the first except dentations are somewhat further from the columella. Third cycle septa join the second and bear three to five dentations. Fourth cycle septa join the third before the columella and bear 3-5 dentations. Fifth cycle septa are very short and appear to be dentate. The lateral faces of all septa bear fine granulations which are arranged in lines sloping towards

Family RHIZANGIIDAE d'Orbigny, 1851

Genus *Oulangia* Milne Edwards and Haime, 1848

Oulangia radames n. sp. Fig. 1-4

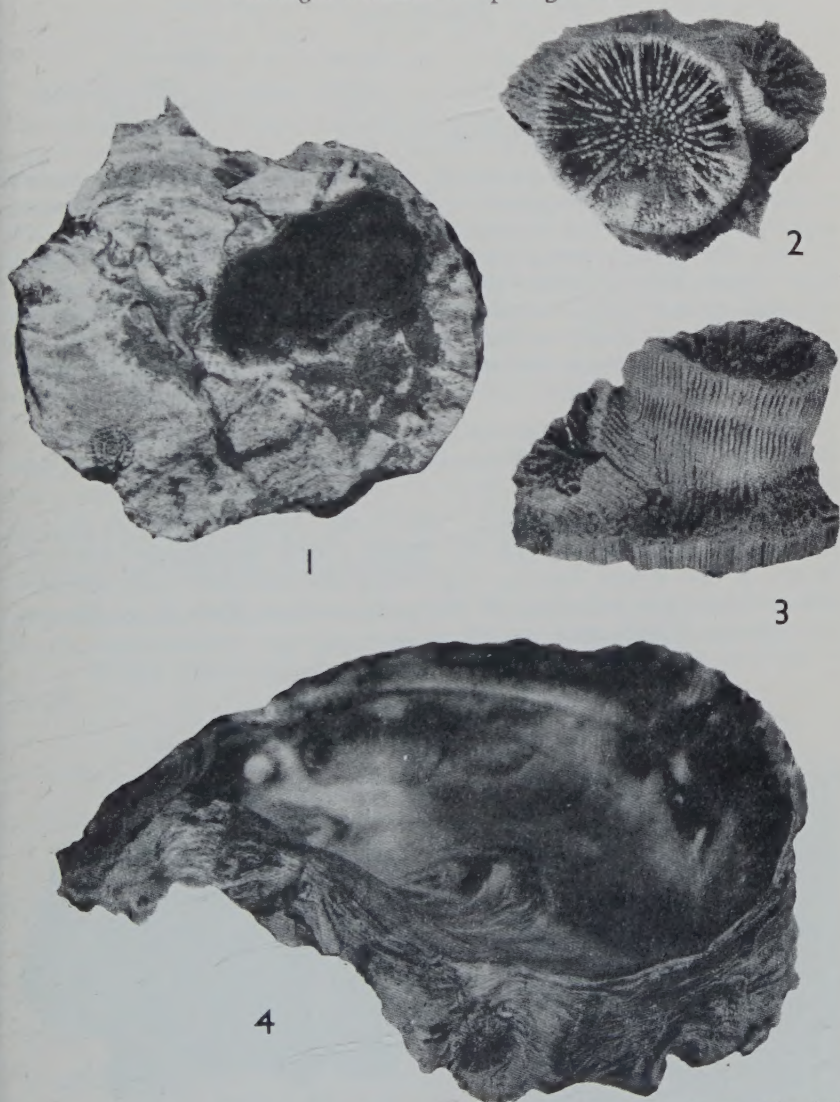


Fig. 1—*Oulangia radames* buried in right valve of *Ostrea* cf. *O. sinuata*. The dark material is a portion of the shell of *Atrina* sp. upon which both the oyster and coral were growing. The view is from the bottom, i.e., the base of the oyster shell. ($\times 1.65$)

Figs. 2, 3—Lateral and calicular views of holotype (N.Z.G.S., CO 1296) of *Oulangia radames* n. sp. ($\times 2.5$)

Fig. 4—Side view of right valve of *Ostrea* cf. *O. sinuata* growing over a specimen of *Oulangia radames*. ($\times 1.5$)

the columella somewhat more steeply than the proximal septal edge. Columella papillose, 20 or more rods being common.

Measurements

	Height (mm)	Diameters (mm)
Holotype	6.0	10.0 × 8.5
Average of ten specimens	5.3	6.6 × 6.5

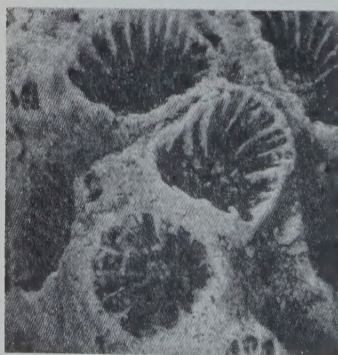
REMARKS: *Oulangia* is distributed widely in the Indo-Pacific, occurring in the Philippines (type species *O. stokesiana* Milne Edwards and Haime), Japan (*O. stokesiana* var. *miltoni* Yabe and Eguchi) and the eastern Pacific (*O. bradleyi* Verrill). It has also been recorded from the Yamikuata Lignite Beds (Pleistocene) of Japan (Yabe and Eguchi, 1932). The present species, representing the earliest occurrence of the genus, is close to *Oulangia stokesiana* in all characters but those of the septal dentation. Both the Philippines and Japanese specimens are more finely dentate and the dentations are closer to the wall.

HOLOTYPE: CO 1296; GS 1173, Mouth of Wai Stream, Hawera. Coll. Uttley and Marwick, 1922. Whenwakura Group, Lower Waitotaran (Upper Pliocene).

OCCURRENCE: Tongaporutuan; GS 7574, 200 yd north of Rapanui Stream, 8 ft above beach. Coll. D. Rodley, 1959. Waitotaran; GS 1173, Mouth of Wai Stream, Hawera. Coll. Uttley and Marwick, 1922; GS 2228, Ohawe Beach, East of mouth of Waingongoro River. Coll. C. A. Fleming, I. G. Speden, D. F. Squires.

Genus *Culicia* Dana, 1846.

Culicia rubeola (Quoy and Gaimard), 1833. Figs. 5-6



5



6

Fig. 5—Calicula view of *Culicia rubeola* (Quoy and Gaimard). (× 3.5)

Fig. 6—Corallum of *Culicia rubeola* (Quoy and Gaimard). (× 2, 3)

Photo: S. N. Beatus

- Dendrophyllia rubeola* Quoy and Gaimard, 1833, Voyage de l'Astrolabe, Zoologie, vol. 4, Zoophytes, p. 97, pl. 15, figs. 12-15.
Culicia rubeola (Quoy and Gaimard). Wells, 1954, U.S. Geol. Surv. Prof. Paper 260-I, p. 464, pl. 185, figs. 3-6 (Synonymy).
Cylicia buttoni Tenison-Woods, 1879, Proc. Linnean Soc. New South Wales, vol. 3, p. 132, pl. 12, fig. 1.

DESCRIPTION: Corallum variable in form. May appear as scattered corallites adhering to rock face or as spirally arranged clusters of corallites growing about antipatharians or other objects. Calices moderately tall, ranging from 2 mm to 6 mm in length. Wall epithecate and thin with the epitheca bearing finely spaced corrugations. Calices average four to five millimetres in diameter. Septa 26-33 in number, those of the first two cycles and portions of the third reaching the columella. Septa of the second group join those of the first about one-half the distance to the columella which consists of a few papilli difficult to distinguish from the dentations of the septa. With the exception of the fourth cycle septa which are minutely dentate, all septa are conspicuously dentate. Septa of the first and second cycles are notched near the wall and bear a large lobe on the proximal margin.

REMARKS: Wells (1954, p. 465) has discussed in detail the characterisation of this species and its synonymy. *Culicia rubeola* is founded upon specimens collected from the Thames River region by Quoy and Gaimard. *Culicia buttoni* (Tenison-Woods) and "*Cylicia*" *vacua* Tenison-Woods were both described from the Wellington region, but the latter was based upon young specimens of *Flabellum campanulatum*.

OCCURRENCE: Nukumaruan; GS 1174, Main Road Wanganui - New Plymouth, approximately $2\frac{1}{2}$ miles west of Kai-iwi. Coll. Uttley and Marwick, 1922. Widely distributed about North Island in depths from intertidal to 30 fm.

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THE MARINE CASTLECLIFFIAN SEDIMENTATION IN CENTRAL HAWKE'S BAY, NEW ZEALAND

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(Received for publication, 26 August 1959)

Summary

The marine, Castlecliffian sedimentation in Central Hawke's Bay is limited to an area between Napier Hill and Black Reef, the fossiliferous sediments having reached a thickness of at least 1,200 ft. The deposition of these sediments has been typically paralic, and indicates that terrestrial and marine conditions alternated in the basin. The downward movement in the basin must have been the result of rather fierce tectonic disturbances, which are now attributed to the southward movements of the New Zealand Overthrust. As the overthrust progressed such stretching developed, that the area between Napier and Cape Kidnappers was literally torn apart. The faulted depression that thus formed was filled with sediments to form the Castlecliffian sequence.

INTRODUCTION

The Castlecliffian, Middle Pleistocene (Fleming, 1957, p. 58) strata of Central Hawke's Bay and particularly those between Clifton and Black Reef (fig. 1) have always attracted considerable interest, and geologists have expressed their opinion as to their age and stratigraphic position on a number of occasions over the last century. Previous geological work has been summarised in the Geology of the Te Aute Subdivision (Kingma, in preparation). A satisfactory explanation for this sedimentation has so far never been given and it is only with the realisation of the broader aspects of the tectonics of the southern part of the North Island as a whole that a solution can be put forward for the development of this narrow marine basin.

The problem always centred around the question as to why the marine Castlecliffian was limited to the area between Napier and Cape Kidnappers and why immediately outside that area no such marine sedimentation had taken place. Also as to why the pre-Castlecliffian strata immediately north and south of this basin were so disturbed tectonically.

THE CASTLECLIFFIAN SEQUENCE

The base of the marine, Castlecliffian sequence is exposed at Black Reef and also six miles southwest of Napier on the northern side of the Tutaekuri Bridge, Taradale. At Black Reef the observed sequence rests on Waitotaran calcareous sandstones and at Taradale on Nukumaruan siltstones. The Castlecliffian strata in both cases are almost similar and consist of fossiliferous sandstones and siltstones alternating with grit and gravel bands, the whole sequence being very pumiceous. The rock sequence may be followed from Black Reef to Clifton for approximately 5 miles, the sequence younging in that direction. Gravels and pumices become more important higher up in the sequence. Occasionally the pumice beds are very pure.

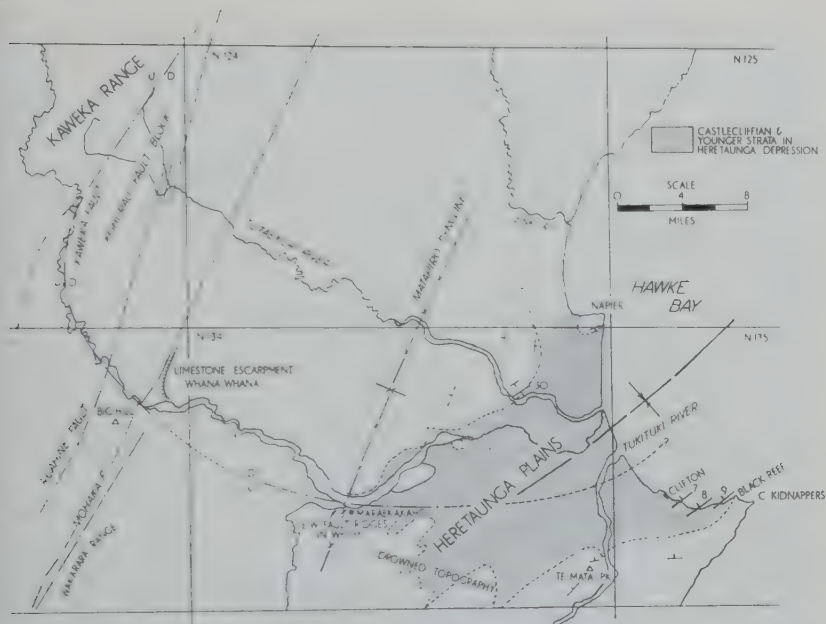


Fig. 1—Outline of Central Hawke's Bay area showing main topographical features and faults.

Lignites, and beds laid down under estuarine conditions, such as dune sands and sandy silts with tree stumps, and marine sandy silts with abundant shells indicate that the sea withdrew from time to time. The sequence is typically paralic and the sea oscillated back and forth causing land conditions to alternate with those of shallow seas (Schuchert, p. 784, 1928).

The age of the sequence was established from mollusca, abundant in the fine-grained marine beds, from which Dr C. A. Fleming has concluded (pers. comm.) that the sediments are Middle to Upper Castlecliffian in age. The Lower Castlecliffian is not recorded in the Black Reef - Clifton section, and may be lower down in the basin.

At Taradale the sequence overlies Nukumaruan siltstones and as the interval of erosion does not appear from field observations to be very great this sequence is possibly Lower Castlecliffian in age.

The lignites have not yielded substantial information as far as pollen is concerned but the pollen extracted from the carbonaceous silts indicate a climate comparable with that of today (Dr R. A. Couper, pers. comm.). If this sequence is to be fitted into a glacial-interglacial system it will certainly coincide with an interglacial.

The Castlecliffian strata unconformably overlie a great variety of older rocks. They penetrate the Tukituki valley for 7-8 miles from the mouth and apparently an initial forming of the Tukituki valley was then already in progress. The fact that they unconformably overlie older rocks indicates that the area was eroding in immediate pre-Castlecliffian time and the present topo-



Photo: T. Mahieu, Auckland.

Fig. 2—Cape Kidnappers section, looking westward from top of Black Reef. White beds are pumiceous silts and sands with varying amounts of pumice. The dark beds are pebbly sandstones and greywacke conglomerates.

graphy was probably on its way to being formed. The present attitude of the Castlecliffian strata is a constant 7–8 degrees dip to the northwest in the Clifton - Black Reef section and with an approximately 30 degree dip to the south-east at Taradale. The beds obviously form a syncline under the Heretaunga Plains (fig. 1). A substantial thickness of beds, probably more than 400 ft, has been removed by erosion since the youngest Castlecliffian beds were laid down. This may be judged from the manner in which post-Castlecliffian terraces cut the Castlecliffian beds and from the small outliers that still occur at high levels in the area south of the bay. The thickness of the sequence as a whole is approximately 1,200 ft – the amount measurable in the Black Reef - Clifton section (fig. 2); but in the axial part of the syncline it is probably much thicker.

TECTONIC IMPLICATIONS

The tectonic implications of this Castlecliffian sedimentation are rather remarkable. The position is that a marine sedimentary basin appears to have developed approximately covering the triangle represented by the present Heretaunga Plains. In this triangle there was local downward movement together with invasion by the sea, while outside the area neither such move-

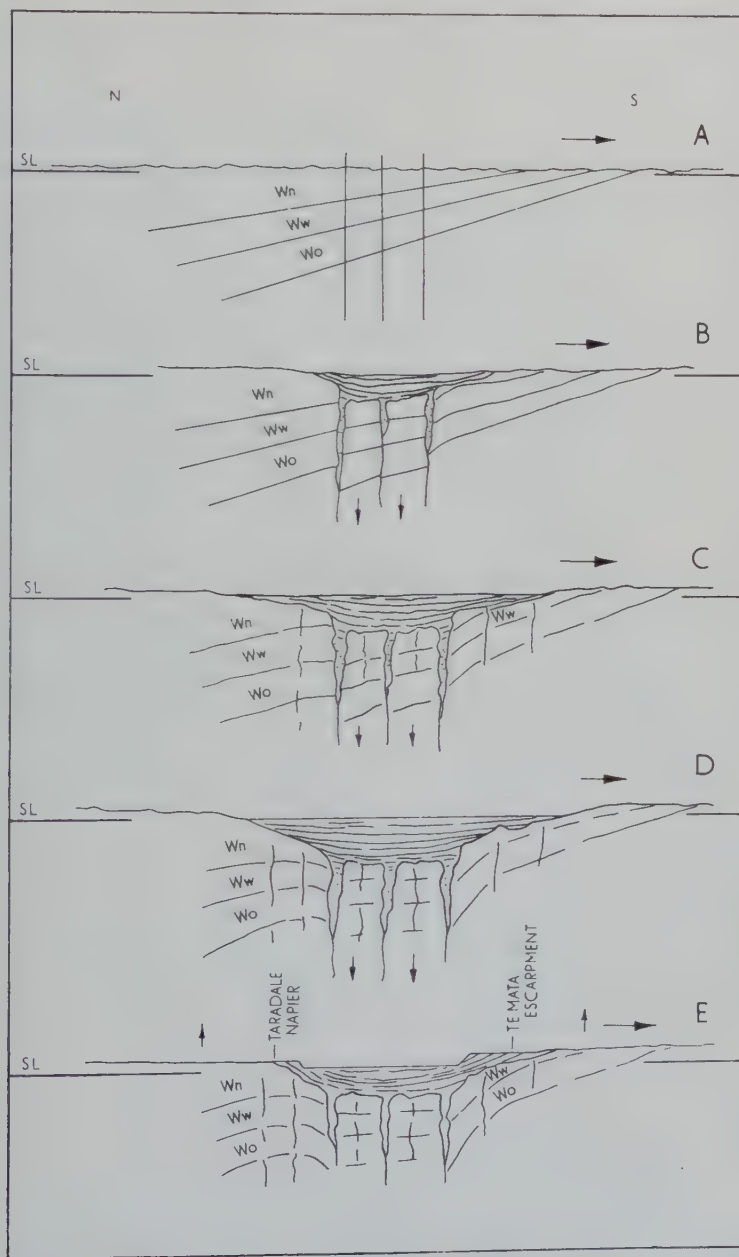


Fig. 3—Time cross-sections through Castlecliffian deposition. A. prior to Castlecliffian deposition, faults not showing movement; B. southern part moving away creating downward movement and consequent sedimentation; C, D. further stages in tectonic sequence and sedimentation; E. uplift of area and erosion, development of Heretaunga Plains. Vertical scale exaggerated.

ments nor the consequent inundation and sedimentation took place. The largest amount of depressive movement was thus limited to the Heretaunga Plains area.

The author has described the movements that influenced the Kohurau district and which resulted in the formation of the Kohurau Fault Block (Kingma, 1957a, b). It was found at the time that this block was bordered at the western side by the semicircular Kaweka Fault, which follows the foot of the Kaweka Range and then continues along the course of the Ngaruroro River as far down as Big Hill and the Mohaka Fault (fig. 1). In the area downstream from the Mohaka Fault, the extension of the Kaweka Fault was always suspected but never fully demonstrated and the offset in the Wai-totaran limestones north and south of the Ngaruroro River, at Whana Whana east of Big Hill, certainly takes place along this fault. At Maraekakaho it is, from east-west running fault ridges in Nukumaruan limestones, quite evident that a substantial fault must run in an east-west direction through that area (fig. 1). It is suggested here that these faults together form one peripheral fault along the southern edge of the cauldron-like depression of the Petane Trough (Kingma, 1959), and the term Kaweka Fault is accepted for the entire fault. The Castlecliffian, marine sedimentary Basin is clearly situated on the extension of this fault, and it is here presumed that the Kaweka Fault extends through the Heretaunga Plains into Hawke Bay.

The development of the Petane Trough has been explained by the author (Kingma, 1959) as the result of the southward movement of the southern part of the North Island as part of the New Zealand Overthrust. Continued movement during latest Nukumaruan and early Castlecliffian times probably ruptured the area along the southern portion of the Petane Trough with consequent downward movement in the area between Napier and Cape Kidnappers. These downward movements pulled the sides of the depression down as may be seen from the attitudes of the lower Napier Hill limestone and in the limestones of the Te Mata Peak Escarpment (fig. 1). The regional strike in central Hawke's Bay is north-north-east, but in the two areas mentioned anomalous strikes occur which probably arise from the downward movement in the Castlecliffian basin (fig. 3).

The development of the basin is thus explained by accepting that the segments between the East Coast transcurrent fault zones moved southward (Kingma, 1958, 1959) leaving a gap behind wherein the Castlecliffian sedimentation took place (figs. 3, 4).

THE SEDIMENTATION

The New Zealand Overthrust probably went through periods of rest and periods of movement. The general tendency however was for the gap between Napier and Cape Kidnappers to widen. From the sedimentary sequence it may be concluded that marine and terrestrial conditions oc-

curred alternately. During the periods of rest the basin filled up and terrestrial conditions ultimately prevailed, probably with vegetation creeping on to mudflats. With the periods of movement the basin sank, accompanied by invasion of the sea, marine life and burial of the earlier terrestrial strata. The sediments were undoubtedly supplied by the antediluvian Hawke's Bay rivers such as the Tutae-kuri, Ngaruroro, and Tukituki. These sedimentary conditions continued into the late Castlecliffian. In Hawera times, extensive terracing took place and the Castlecliffian sedimentation had come to a close. In Holocene time the entire area was uplifted and considerable thicknesses of Castlecliffian sediments have been eroded (fig. 3). It seems possible that with renewed movement on the New Zealand Overthrust, the transcurrent, East Coast segments will again move southward with consequent downward movement in the Heretaunga Basin and invasion by the sea.

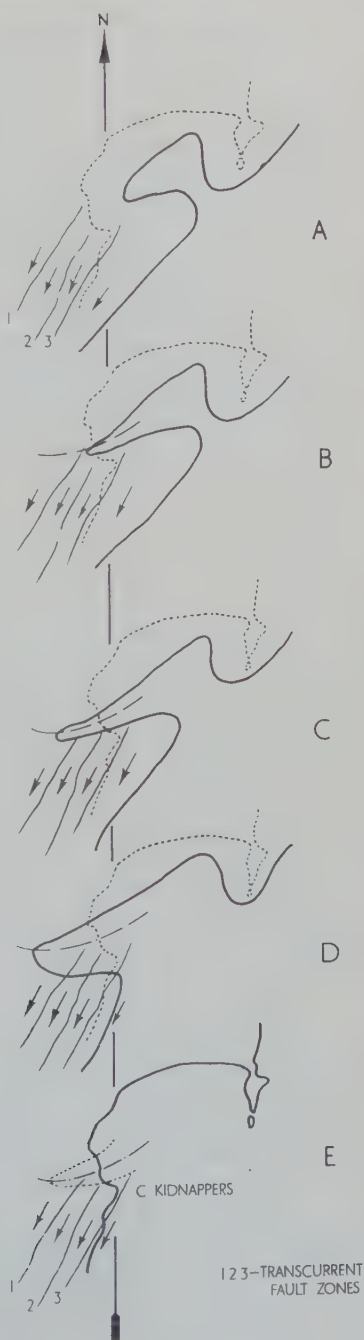


Fig. 4, A, B, C, D—Hypothetical historical development of the Hawke Bay Segments between transcurrent fault zones moving southward and away from remainder of bay area. E. final outline of Hawke Bay and Heretaunga depression.

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PLIOCENE AND PLEISTOCENE PLANT MICROFOSSILS FROM DRILLHOLES NEAR FRANKTON, NEW ZEALAND

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(Received for publication, 10 June 1959)

Summary

Plant microfossil samples from drillholes near Frankton, through some 700 ft of pumiceous and non-pumiceous sand, silt, clay and lignitic beds, range in age from Waitotaran (Upper Pliocene) to Upper Pleistocene or younger. The Plio-Pleistocene (Waitotaran-Nukumaruan) boundary is clearly shown where a sub-tropical Waitotaran vegetation is replaced by a Lower Nukumaruan vegetation, indicating a climate cooler than that of the present day. A brief comparison is made with similar Plio-Pleistocene sequences elsewhere in New Zealand.

INTRODUCTION

In March 1956, Mr J. C. Schofield, New Zealand Geological Survey, Otahuhu, collected some 40 samples for plant microfossil study from two drillholes near Frankton (fig. 1). The first hole (N65/2/20) on the southern side of Aberfoyle Road (grid. ref. N65 760469) was drilled to a depth of 500 ft before Mr Schofield was informed, so that samples and details of lithology are available only from 500 to 741 ft. A second hole (N65/2/21) was drilled, 40 yd in a southerly direction from the first hole. From this hole a full collection of samples and a detailed account of lithology are available to a depth of 560 ft. Sufficient overlap is provided to correlate the two holes.

Stratigraphic columns were compiled from the logs of the drillholes showing lithology and positions of samples (fig. 2). The lithological descriptions of the upper 500 ft of drillhole N65/2/20 are taken from the drillers' descriptions. Mr Schofield also provided the writers with comments on important changes in lithology, which can be summarised as follows.

Pumice, as identified under a hand lens, is absent at depths below 400 ft. Black sand and derived andesitic material occurs from 450 to 535 ft. At 535 ft there is a marked change from predominantly sands above, to predominantly clays below (see drillhole N65 2/20). A zone of calcareous clay and cemented, rewashed andesitic tuff is present in both holes between 488 and 520 ft. Samples N65/546 and 548 from this zone were examined for Foraminifera but none were found.

Numerous carbonaceous beds occur throughout both drillholes with the exception of the calcareous andesitic zone. Above this zone, the carbonaceous beds are well defined peat horizons but below they are thin bands in clay and in interbedded clay and sand.

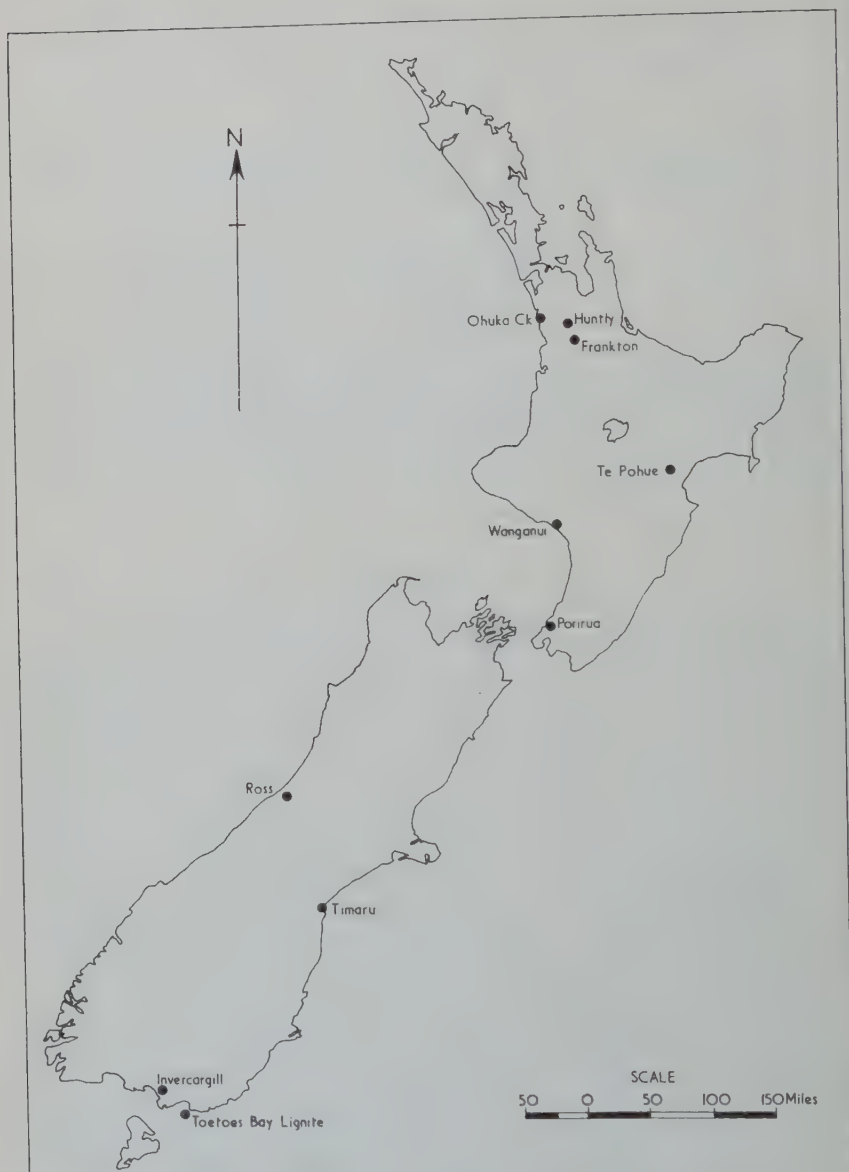


FIG. 1: Locality map.

FLORA OF THE FRANKTON DRILLHOLES

Most of the 40 samples examined yielded reasonable pollen preparations allowing age determinations and conclusions regarding vegetational and climatic changes to be made.

COUPER AND HARRIS — PLANT MICROFOSSILS

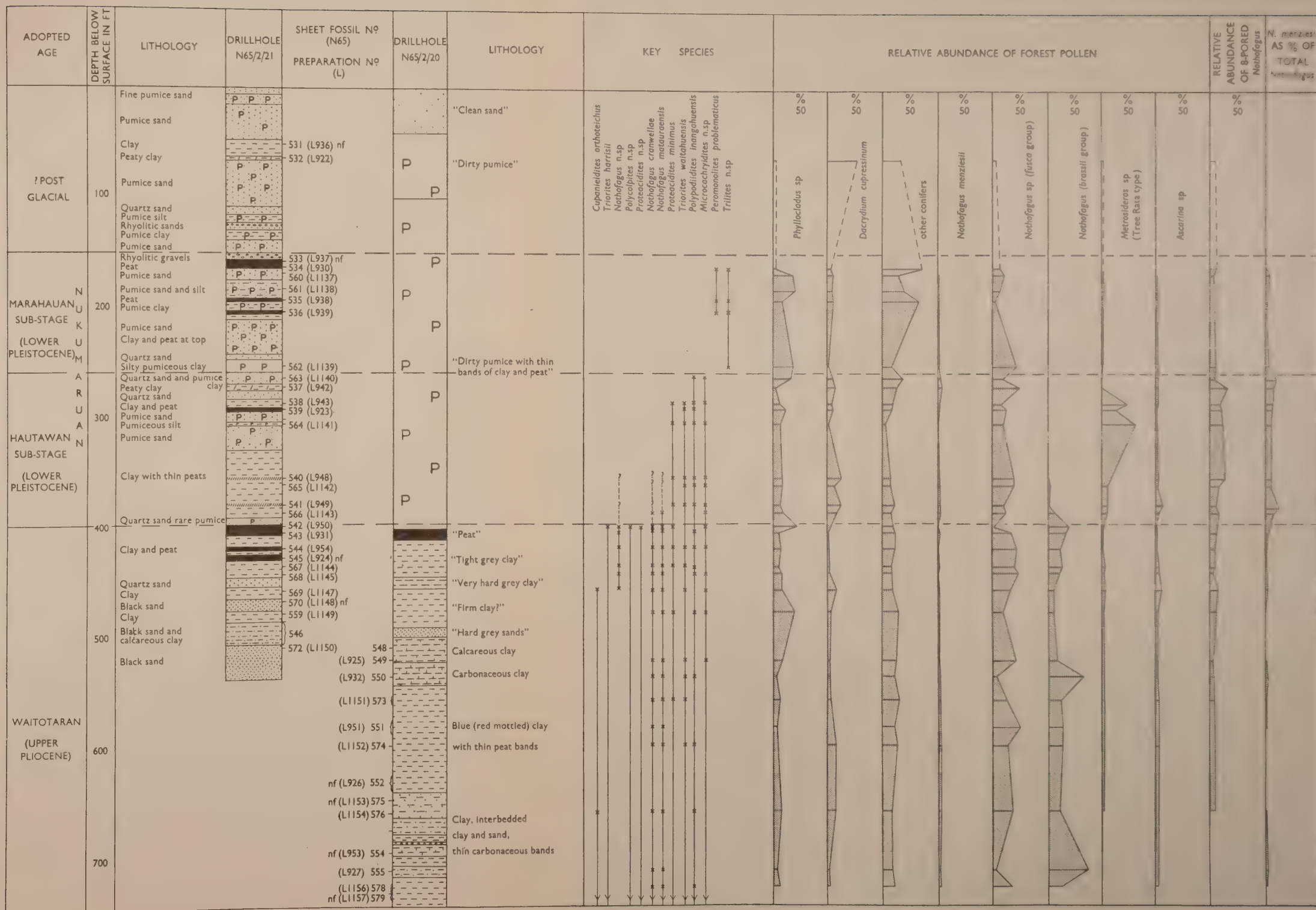


FIG. 2: Pollen diagram from Frankton drillhole.

The plants identified from spores and pollen grains are listed in Table 1. In the Waitotaran and Nukumaruan beds are found spore and pollen species (most of which make their first appearance in earlier Tertiary beds) of which the parent plants are not known. These species are marked with an asterisk in Table 1 and their botanical affinities are discussed below under the heading "Vegetational and Climatic Changes".

AGE OF THE SEDIMENTS

Waitotaran

Samples from depths of 595 to 730 ft contain abundant specimens of *Nothofagus matauraensis*, *N. cranwellae*, *Nothofagus* n. sp. and rarer specimens of *Cupanieidites orthoteichus* and *Polycopites* n. sp., all of which are known only from Waitotaran and older beds elsewhere in New Zealand. *Triorites harrisii*, which is abundant in Opoitian and older Tertiary beds, was identified only in samples N65/542, 574. A few other species, including *Ixerba* sp., *Myrtus* sp., *Quintinia* sp. and *Salicornia* sp., are known only from Waitotaran and younger beds.

The evidence of the above species, the similarity of the floras as a whole to those from well-dated Waitotaran sediments elsewhere, and their stratigraphic position below beds containing evidence of the now well-established Lower Nukumaruan climatic cooling (Couper and McQueen, 1954) leave little doubt that the sediments from 395 to 730 ft should be classed as Waitotaran (Upper Pliocene).

No microplankton (hystrichosphaerids) were identified in the above Waitotaran sediments, suggesting that they were deposited in a non-marine environment. Waitotaran marine beds are known, however, from a drillhole near Huntly, some 13 miles north of Frankton. A small molluscan fauna (N65/605-GS 6200) from a shell-bed at a depth of 87-97.5 ft at Huntly is considered Waitotaran and correlated with the Otahuhu shell-bed (Dr C. A. Fleming, New Zealand Geological Survey, pers. comm.).

Lower Nukumaruan (Hautawan Substage)

Samples from 253 to 388 ft in drillhole N65/2/21 contain *Triorites waitahuensis*, *Microcachryidites* n. sp. *Polypodiidites inangahuensis* and *Proteacidites minimus*, all comparatively long-ranging Tertiary species which make their last appearance in the Lower Nukumaruan (Hautawan Substage, Fleming, 1953). The characteristic Waitotaran species *Nothofagus matauraensis* and *N. cranwellae* are known only from samples N65/540, 541, where they are less than 0.5% of the total pollen count, and from N65/566, where they are slightly more common (2% of the total). Considering also the evidence of a cooler climate than that of the present (see discussion below) the sediments between 253 and 388 ft can be assigned with confidence to the Lower Nukumaruan (Lower Pleistocene).

A similar floral succession from Waitotaran to Lower Nukumaruan is known from a number of sections in New Zealand. For example, sample N124/554 from the Waitotaran Te Aute Limestone near the Te Pohue Hotel, Napier-Taupo Road (grid. ref N124/118688), which is dominated by *Nothofagus cranwellae* and *N. matauraensis*, is conformably overlain by

Lower Nukumaruan marine siltstone (N124/553) in which *N. cranwellae* and *N. matauraensis* are very rare (less than 1% of the total pollen types identified). *Triorites waitahuensis* and *Polypodiidites inangahuensis* are also present in the latter sample. In the South Island, sample S111/531 from marine silts at a depth of 413 ft in a drillhole near the locomotive sheds, Timaru (grid. ref. S111/788503) contains abundant specimens of *Nothofagus cranwellae* and *N. matauraensis*. These samples are immediately above a shell bed which contains poorly preserved Mollusca (S111/529, GS 7234) of Waitotaran–Lower Nukumaruan age (probably the former – A. U. E. Boreham, N.Z. Geological Survey, pers. comm.). Higher in the Timaru drillhole, (S111/542, 543 at a depth of 260–270 ft), the beds contain floras in which *N. cranwellae* and *N. matauraensis* are either very rare or absent. *Microcachryidites* n. sp. (last appearance Lower Nukumaruan) is present in both samples.

? Upper Nukumaruan (Marahauan Substage)

Samples N65/533–536, 560–562 from 148 to 253 ft in drillhole N65/2/21 all yielded abundant pollen, but extinct species are very rare. *Peromonolites problematicus* and *Trilites* n. sp. are present in N/65/533, 535, 536, and 562. The former species is known elsewhere from the Lower Maxwell Formation, Wanganui (N137/506) of Upper Nukumaruan age (Marahauan Substage, Fleming, 1953), from the Toetoes Bay submarine lignite of probably Upper Nukumaruan age (Couper, 1951) and from samples S177/514, 515 from Invercargill Waterworks Bore No. 1, Queens Park. The Invercargill samples are some 100 ft stratigraphically above Lower Nukumaruan sediments in the same drillhole and are probably Upper Nukumaruan. *Trilites* n. sp. is known elsewhere only from Pleistocene sediments exposed near Porirua, Wellington (N160/550). This sample is post-Lower Nukumaruan but the upper age limit is not known.

The sediments from 148 to 253 ft in N65/2/21 are post-Lower Nukumaruan and, on the evidence of *Peromonolites problematicus* possibly Upper Nukumaruan.

Post-Nukumaruan

Only one sample (N65/532) yielded a flora. It lacks extinct species and its age can be assessed only as post-Nukumaruan.

VEGETATIONAL AND CLIMATIC CHANGES

Waitotaran

Changes in the forest vegetation and stratigraphic distribution of key species are shown in fig. 2.

Nothofagus matauraensis (first appearance Eocene), *N. cranwellae* (first appearance Middle Oligocene) and *Nothofagus* n. sp. (?Waitotaran only) belong to the *Nothofagus brassii* group of southern beeches (Cookson and Pike, 1955; Harris, 1956). Their living representatives are known today only in New Guinea and New Caledonia. In New Zealand, throughout most of the Middle and Upper Tertiary up to the end of Waitotaran times,

N. matauraensis and *N. cranwellae* are among the most widespread and abundant of all pollen species. *Nothofagus* pollen grains of the *brassii* group are also widespread and abundant in Australia in Tertiary times. In both countries they are associated with a number of pollen species, including members of the families Bombacaceae, Sapindaceae (*Cupanieidites ortho-teichus* of the tribe Cupanieae), Proteaceae (numerous species) and Ephedraceae (*Ephedra notensis* Cookson) whose living representatives like those of the *brassii* group are also known today only from tropical and sub-tropical areas. Besides pollen of these extinct species, grains of other warmth-loving plants such as *Agathis* (kauri), *Dysoxylum spectabile*, *Ixerba*, *Quintinia*, *Rhopalostylis sapida* and *Knightia excelsa* (all still living in the warmer parts of New Zealand) are common in Waitotaran floras. The sudden disappearance at the end of the Waitotaran of many representatives of a sub-tropical to tropical flora (see fig. 2) is therefore of climatic as well as stratigraphic significance.

Lower Nukumaruan

Lower Nukumaruan floras throughout New Zealand show evidence of cooler conditions than those of the present day and are classed as Lower Pleistocene (Couper and McQueen, 1954). In marked contrast to the Waitotaran forest vegetation, that of the Lower Nukumaruan of drillhole N65/2/21 is dominated by *Nothofagus* sp. (*fusca* group) and *Phyllocladus* sp., with lesser *Nothofagus menziesii*, *Dacrydium cupressinum*, *Podocarpus* sp., *Metrosideros* sp. and *Ascarina* sp. Statistical analysis of pore numbers of the *Nothofagus* pollen (Harris, 1956) suggests that mountain beech (*N. cliffortioides*) is present (see fig. 2). This suggestion is strengthened by the presence of leaves of *N. cliffortioides* in Lower Nukumaruan beds (N55/522) at Ohuka Creek, about 25 miles to the north-west (Couper and McQueen, 1954). Pollen of *Nothofagus menziesii* shows a striking increase, relative to the pollen of other species of *Nothofagus* in the Lower Nukumaruan of drillhole N65/2/21 (see fig. 2 where the relative abundance of *N. menziesii* pollen is expressed as a percentage of total *Nothofagus* pollen).

The Lower Nukumaruan forest vegetation of drillhole N65/2/21 provides an interesting contrast with that of Recent peat samples from the same district. A pollen profile through 6.25 m of Recent peat at Rukuhia, 6 miles south of Frankton shows a completely different forest vegetation dominated by *Dacrydium cupressinum*, *Podocarpus* spp. with *Nothofagus* spp., *Phyllocladus* sp. and *Metrosideros* sp. either very rare or absent. The Lower Nukumaruan vegetation of drillhole N65/2/21 is interpreted as indicating markedly cooler conditions than those of the Waitotaran and almost certainly cooler conditions than those of the present day.

Other Lower Nukumaruan floras from the Auckland area such as the Ohuka Creek flora (N55/522) described (as Upper Nukumaruan) by Couper and McQueen (1954 and from Hawke's Bay (N124/553 already discussed above, have a similar vegetation dominated by *Nothofagus* spp. In the South Island, some Lower Nukumaruan sediments, such as the Ross glacial beds (Couper and McQueen, 1954) and samples S111/542, 543, 140 ft above a Waitotaran or Lower Nukumaruan shell bed in a New Zea-

land Railways borehole, near Timaru, have floras in which pollen representing grassland and scrub of a sub-alpine or sub-antarctic nature (Compositae, Gramineae and certain other species) are as abundant as forest pollens. The forest vegetation in these and other Lower Nukumaruan samples from the South Island is generally represented by abundant *Nothofagus menziesii*, *Nothofagus* sp. (*fusca* group) and *Phyllocladus*, with other conifers comparatively rare or absent. Such a vegetation is interpreted as indicating a cooler climate than that of the more northern latitudes of Auckland and Hawke's Bay.

Upper Nukumaruan

The probable Upper Nukumaruan sediments in drillhole N65/2/21 have floras in which the forest vegetation is dominated by *Podocarpus* spp. and to a lesser extent by *Phyllocladus* sp. Compared with the Lower Nukumaruan vegetation (see fig. 1), *Nothofagus* sp. (*fusca* group) and *Dacrydium cupressinum* are unimportant and *N. menziesii*, *Metrosideros* sp. and *Ascarina* sp. are either absent or extremely rare. The vegetation suggests warmer conditions than in the Lower Nukumaruan.

Post Nukumaruan

The remaining sample (N65/532) from drillhole N65/2/21 is from beds which Mr Schofield considers may be as young as post-glacial. The forest vegetation represented by plant micro-fossils is similar in every respect to that of the Recent peat profile from Rukuhia and suggests a climate similar to that of the present day.

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TABLE I. Plants Identified from Frankton Drillholes

Species and Depth (ft)

Sphagnum sp., 532, 538, 540, 542, 543, 544, 560, 564, 565, 568, 569, 573, 576.
Lycopodium cf. *australianum* Nerter, 563.
Lycopodium (*billardieri* group), 532, 542, 562, 563, 567, 568.
Lycopodium (*fastigiatum* group), 532, 538, 559, 561, 569.
Lycopodium cernuum L., 561.
Lycopodium densum Labill, 564.
Gleichenia circinata Swartz, 532, 534-536, 537-544, 549, 551, 559-569, 574, 576, 578.
Sticherus spp., 544, 562, 563.

- Hymenophyllum* spp., 544, 549, 550, 555, 561, 563–566, 576.
Hymenophyllum cf. *scabrum* A., Rich cf. *sanguinolentum* (Forst. f) Swartz, 542.
Hymenophyllum cf. *bivalve* (Forst. f), Schroeder, 538.
Dicksonia fibrosa Col., 536, 539, 544.
Dicksonia squarrosa Swartz, 534–536, 538–541, 549, 550, 555, 559, 560, 562, 563, 565, 567–569, 573, 574, 576.
Cyathea cf. *colensoi* (Hook f), Domin. cf. *smithii* Hook. f., 532, 536–538, 540–544, 549–551, 555, 559, 563, 565–569, 573, 574, 576, 578.
Cyathea dealbata (Forst. f), Swartz, 532, 534–536, 538–544, 549–551, 555, 559, 562, 563, 565–569, 573, 574, 576, 578.
Cyathea medullaris (Forst. f.), Swartz, 559, 560, 564–569, 573, 574.
Microsorium diversifolium (Willd.) Copel., 534, 538–544, 555, 559, 562, 564–569, 573, 576, 578.
**Polypodioides inangabuensis* Couper, 538–541, 543, 544, 550, 559, 563–565, 567, 568, 574, 576, 578.
? *Anarthropteris dictyopteris* (Mett.) Copel., 574.
Histiopteris incisa (Thunb.) J. Smith, 538, 560–562, 564–566, 569, 573.
Paesia scaberula (A. Rich) Kuhn, 562.
Pteridium aquilinum (L.) Kuhn, 544, 564–566.
Pteris sp., 532, 539–543, 569, 574.
Blechnum spp., 532, 534, 537–543, 549–551, 555, 559, 562–564, 566, 567, 573, 576.
Crenitis glabella (A. Cunn.) Copel., 574.
Adiantum sp., 564.
**Trilites* n. sp., 534–536, 562.
Agathis australis Salisb., 534, 538, 544, 562, 567–569.
Phyllocladus sp., 532, 534–544, 549–551, 555, 559–569, 573, 576, 578.
Dacrydium cupressinum Soland., 532, 534, 535, 537–544, 549, 550, 555, 559–569, 573, 574, 576, 578.
Dacrydium sp. (*biduillii* group), 540, 541, 559, 561–563, 565–567, 569, 573.
Podocarpus cf. *totara* D. Don., 532, 535, 536, 542–544, 549–551, 559, 562, 565–567, 569.
Podocarpus cf. *ferrugineus* D. Don., cf. *spicatus* R. Br., 532, 534, 535, 537–544, 549–551, 555, 559–569, 573, 574, 576, 578.
Podocarpus dacrydioides A. Rich, 532, 534, 535, 537–544, 549, 550, 555, 559, 560, 562, 563, 565–569, 573, 574, 576, 578.
**Microcachyidites* n. sp., 538, 540–542, 544, 549, 595, 563–566, 568, 569.
Libocedrus sp., 532, 578.
Pseudowintera sp., 578.
Laurelia novaezelandiae A. Cunn., 538, 542, 565, 567, 569, 573, 574.
Rbagodia sp., 564.
Myriophyllum sp., 532, 534, 537, 539, 541, 562.
Haloragis sp., 536, 561, 562, 564, 578.
Knightia excelsa R. Br., 535, 538, 540, 542, 544, 564–566, 568, 569, 573.
**Proteacidites minimus* Couper, 538, 540–542, 544, 559, 564, 567, 573.
**Proteacidites* n. sp., 542.
Epilobium sp., 539, 563.
Fuchsia sp., 555.
Leptospermum sp., 532, 536, 537, 539, 542–544, 562, 564, 566, 567, 576.
Metrosideros sp., 532, 538, 539, 541–544, 559, 562, 564–569, 573, 576.
Myrtus sp., 538, 544.
Plagianthus sp., 534, 535, 537, 540, 541, 563.
Hoheria sp., 539, 541, 549, 562, 566–569, 573.
Carpodetus sp., 573.
Ixerba sp., 542, 550, 568.
Quintinia sp., 544, 559.
Ascarina sp., 537–544, 549, 550, 559, 560, 565–569, 573, 574, 578.
Nothofagus menziesii (Hook. f.) Oerst., 535, 537–541, 543, 544, 549, 550, 555, 560, 562–567, 569, 573, 574, 576, 578.
Nothofagus sp. (*fusca* group), All samples.
**Nothofagus cramwellae* Couper 542–544, 549–551, 555, 559, 566–569, 573, 574, 576, 578.

- **Nothofagus matauraensis* Couper, 542-544, 549-551, 555, 559, 566-569, 573, 574, 576, 578.
**Nothofagus* n. sp., 542-544, 567-569.
Elytranthe sp., 538, 540, 541, 567.
Dysoxylum spectabile Hook. f., 542, 555, 559, 567, 569, 576.
**Cupanieidites orthoteichus* Cookson, 569, 576.
Dodonaea sp., 566.
Dracophyllum sp., 534-544, 549-551, 555, 559, 560, 562-565, 567-569, 573, 576, 578.
Epacris sp., 537, 544, 562, 564, 568.
Suttonia sp., 532, 534-536, 538-541, 543, 549, 562, 566, 568.
Coprosma sp., 532, 534-544, 549, 550, 555, 559, 560-566, 568, 569, 573, 576.
Taraxacum sp., 535, 536, 550, 563, 574, 576.
Elaeocarpaceae, 562, 566.
Chenopodiaceae, 537, 540, 541, 549, 562, 564-566, 569.
Cruciferae, 569.
Araliaceae, 532, 538, 539, 544, 559, 560, 562, 564-568, 574, 576.
Campanulaceae, 563, 564.
Compositae, 532, 534-544, 549, 550, 555, 559-569, 573, 578.

PETROCHEMISTRY OF THE AUCKLAND BASALTS

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Summary

Thirteen new analyses of lavas from Auckland are presented and discussed. The rocks are shown to be olivine-rich alkaline basalts, chemically comparable with lavas from the Pacific basin but possibly derived by crystallisation fractionation along a trend characteristic of a continental environment. The composition of the Auckland rocks is compared with that of Pliocene-Pleistocene basalts from Northland and from South Auckland. The origin of olivine nodules and a nepheline basanite associated with the Auckland basalts is considered.

INTRODUCTION

Through the courtesy of the Directors of the New Zealand Geological Survey and of the Dominion Laboratory, thirteen new analyses of local volcanic rocks have been made for the writer by Mr J. A. Ritchie. All are of olivine basalts, mostly from flows emanating from various eruptive centres in the Auckland volcanic field. Detailed petrographic description of the volcanic rocks of this district will be made in a further contribution; it is sufficient here to note that in thin section the rocks show themselves to be rather fine-grained in texture and to possess the following mineralogical characteristics:

Olivine is in coarse phenocrysts and seldom appears in the groundmass; clinopyroxene – usually more or less titaniferous, judging from the colour and pleochroism – is present both as phenocrysts and as granules in the groundmass; the bulk of the feldspar is generally limited to the groundmass but occasionally plagioclase is microphenocrystal and more rarely in laths of larger size; iron ore, dominantly magnetite, is abundant in all sections examined.

In the following discussion these new analyses are considered together with an earlier one by Washington (1917) of a soda-rich, nepheline-bearing rock which occurs sporadically as blocks in the pyroclastic accumulations surrounding the eruptive vents of the Auckland Domain and which was described many years ago by Marshall (1912) as a nepheline basanite. The calculation of an "average Auckland basalt" has been based on the thirteen analyses, that of the Domain rock has been excluded since by its chemical nature, mode of occurrence and mineralogical character it is clearly a late differentiate. Its inclusion with the analyses of the basalts would obviously falsify the chemical constitution of the "average" rock. In the tables and discussion the analyses are referred to by serial numbers given in the following list which provides also the localities, the New Zealand Geological Survey serial numbers of the analyses and other data concerning the samples analysed:

Number	Locality (map ref. to N.Z.M.S. Series 1. Sheet N. 42)	Originating Centre and Notes on Samples	N.Z.G.S. Serial Numbers of Analyses
1	416564	Pigeon Mt. Core from bore inside crater. Moderately coarse-grained basalt with large euhedral olivine phenocrysts.	P21036
2	237556	Mt. Albert. From late flow from west flank of summit of cone. Coarse-grained; abundant pyroxene; feldspar in phenocrysts.	P21037
3	272543	Three Kings. From lava flow on south side within tuff ring. Olivines, large - majority rounded; pyroxene granular.	P21038
4	329575	Mt. Smart. From flow in road cutting on west side of cone. Vesicular and rather glassy olivine basalt.	P21039
5	324634	Flow near North Head, Devonport, probably from Duders Hill (now removed). Picritic type. Pyroxene is pale-mauve and pleochroic.	P21040
6	298567	Mt. St. John. Central portion of large block in crater. Feldspathic type; olivine rimmed with iddingsite; pyroxene colourless.	P21041
7	300576	Mt. Hobson. From flow in rail cutting near footbridge. Picritic type.	P21042
8	442344	Papatoetoe Crater. From flow inside tuff ring. Intergranular olivine basalt. Feldspar as moderately coarse micro-phenocrysts; abundant pale-mauve pyroxene.	P21043
9	278690	Pupuke. From flow near Birkenhead pumping station.	P21044
10	322558	One Tree Hill. From cores at Members' Stand, Ellerslie racecourse. Coarse-grained olivine basalt.	P18040
11	292585	Mt. Eden. Alton Road; from flow on north-east side of cone.	P18041
12	333540	Mt. Wellington. Michaels Ave.; from late flow.	P18042
13	275468	Puketutu Island. Flow on northern fore-shore.	P18043

Ave. = Hypothetical rock developed from 13 analyses; constituents averaged and recalculated to a total of 100 per cent.

Dom. = Basanite of Auckland Domain.

TABLE 1: Analyses of Basalts A. Results with Auckland Samples. B. Molecular Norms

A. Results with Auckland Samples

	1	2	3	4	5	6	7	8	9	10	11	12	13	Ave	Dom
SiO ₂	43.0	45.4	43.2	44.1	41.9	46.6	43.4	46.1	45.7	48.2	46.5	44.8	43.9	44.8	46.66
TiO ₂	2.24	1.94	2.00	1.94	2.1	1.82	1.96	1.82	2.0	1.42	1.74	2.18	2.33	1.96	3.0
Al ₂ O ₃	12.7	14.3	13.6	12.9	13.6	14.6	13.2	13.6	12.8	14.6	14.7	15.1	14.6	13.86	18.57
Fe ₂ O ₃	2.8	2.3	3.0	4.4	4.1	2.9	4.1	2.0	3.4	2.0	3.3	1.6	1.9	2.91	2.14
FeO	10.2	10.0	9.8	8.6	9.4	9.6	8.4	10.3	9.9	9.8	8.9	10.3	10.1	9.63	7.48
MnO	0.15	0.12	0.12	0.18	0.2	0.18	0.17	0.17	0.18	0.17	0.18	0.2	0.17	0.17	0.19
MgO	12.2	10.2	12.1	11.2	10.6	9.5	12.6	11.4	10.6	10.4	10.6	10.4	12.2	11.07	2.93
CaO	10.7	10.1	10.5	10.6	10.5	9.9	10.6	10.1	10.0	9.6	9.6	10.1	9.8	10.16	7.93
Na ₂ O	3.1	3.1	3.1	3.0	3.5	3.0	3.0	2.8	3.0	2.7	3.1	3.4	2.7	3.19	6.49
K ₂ O	1.4	1.3	0.9	1.3	1.6	1.0	0.9	0.8	0.8	0.65	0.9	1.3	1.3	1.09	2.79
H ₂ O +	0.6	0.35	0.15	0.8	0.95	0.65	0.7	0.45	0.6	0.5	0.35	0.35	0.65	0.73	0.7
H ₂ O -	0.1	0.15	0.35	0.2	0.15	0.15	0.4	0.05	0.2	0.05	0.05	0.05	0.10	0.10	0.2
P ₂ O ₅	0.6	0.48	0.59	0.6	0.91	0.5	0.5	0.47	0.6	0.34	0.53	0.62	0.45	0.55	0.40
	99.89	99.74	99.41	99.82	99.66	100.4	99.93	100.06	99.78	100.43	100.45	100.4	100.2	100	99.48

B. Molecular Norms

	Or	Ab	An	Ne	Wo	En	Fs	Fo	Fa	Ap	Il	Mt	Lc
	7.35	7.6	5.65	20.95	16.75	16.5	12.96	12.18	14.55	7.54	1.23	3.2	2.85
	5.3	3.4	20.3	14.7	13.68	10.9	8.5	8.5	7.7	0.99	2.6	2.4	0.52
	7.75	4.71	17.65	13.68	13.62	10.9	8.5	8.5	7.7	0.99	2.6	2.4	0.52
	9.35	2.4	16.33	17.17	11.6	8.95	2.65	2.65	15.19	6.13	1.92	2.96	6.6
	5.6	16.0	22.6	7.5	10.6	7.9	2.7	2.7	13.9	6.5	1.04	3.05	2.6
	5.3	6.9	19.9	12.4	11.89	9.48	2.46	2.46	19.03	6.6	1.03	2.72	4.24
	4.7	13.6	22.9	6.5	9.24	6.48	2.76	2.76	18.84	10.66	0.96	2.5	2.07
	4.85	21.8	19.58	3.42	7.84	5.8	2.04	2.04	18.3	8.6	1.28	2.84	3.61
	3.95	21.45	25.5	1.58	7.94	5.6	2.3	2.3	17.4	9.5	0.7	1.04	2.22
	6.0	16.75	23.0	6.5	8.24	6.25	1.99	1.99	17.21	7.11	1.09	2.52	3.39
	7.6	8.3	21.7	12.7	9.52	6.6	2.92	2.92	16.05	8.94	1.28	2.74	1.64
	8.0	3.8	22.3	12.2	9.34	7.02	2.32	2.32	19.18	9.04	0.93	3.2	1.95
	6.4	9.6	20.2	11.3	10.54	7.84	2.7	2.7	17.08	7.36	1.15	2.7	3.02
	16.55	13.0	12.95	27.0	9.54	5.44	4.1	4.1	2.07	2.08	0.83	4.16	2.24

TABLE 2: Rarer elements detected by spectrographic analysis in samples of Auckland basalts

Sample Nos.	(10)	(11)	(12)	(13)
Ba	0.005	0.007	0.01	0.007
Sr	0.03	0.03	0.04	0.04
V	0.03	0.03	0.03	0.03
Cr	0.07	0.1	0.05	0.07
Ni	0.02	0.03	0.03	0.03

Mo, Co, B each less than 0.01.

Zn less than 0.10.

Bi, W, Pb, Sn, As, Cd, Be - not detected.

The raw analyses are set out in the first part of table 1 and in the second part are given the molecular norms calculated by the method of Bath (1952) so that the resultant percentages are molecular proportions. Table 2 gives the percentages by weight of the minor elementary constituents of four of the samples as determined by spectrographic analysis. For table 3, the data has been manipulated to provide the percentages of cations in standard unit cells of 160 oxygen atoms and so affords a volumetric rather than a gravimetric picture of the constitution. The Niggli values of the various rocks have also been calculated and are presented in the same table.

Consideration of the data presented shows that the rocks, originating from different centres of emission and erupted at different times during a period of activity extending over more than 42,000 years of Recent and late Pleistocene times, show a uniform chemical composition on analysis, just as they are notably similar when examined in thin section. In all analyses silica is low and ranges from 41.9% in sample No. 5 to 48.2% in sample No. 10; the calculated average basalt has 44.8% of silica. Magnesium oxide, ferrous oxide and calcium oxide are present in substantially equal amounts, approximately 10% by weight. Magnesium oxide is usually a little in excess of each of the others, and it will be noted from Table 3 that the Niggli value mg (the ratio of the molecular proportion of MgO to that of the oxides of Mg , total Fe and Mn) is in all cases greater than 0.5 and less than 0.63. Calcium oxide and alumina are both consistently less abundant than would normally be expected in basaltic rocks, and sodium and potassium oxides are both present in larger amounts than is usual in olivine basalts of continental areas. The parameter k , defining the ratio of the molecular proportions $K_2O : (K_2O + Na_2O)$ varies between the limits of 0.12 and 0.38.

In the variation diagrams, fig. 1, it is seen that an increase in the proportion of silica is accompanied by a general decrease in alkalis and a tendency to decrease on the part of the major basic oxides; alumina, however, shows a tendency to vary sympathetically with the silica. In the case both of titania and of phosphorus pentoxide, the tendency is to decrease as silica increases.

The relatively high alkali, and especially high soda content shown by the analyses is reflected in the presence of nepheline in the norms of all rocks and of normative leucite in one analysis. Further, the nepheline is in noteworthy quantities for its molecular normative percentages range from 1.58% to as high as 17.17%. The constant occurrence of normative nepheline in the

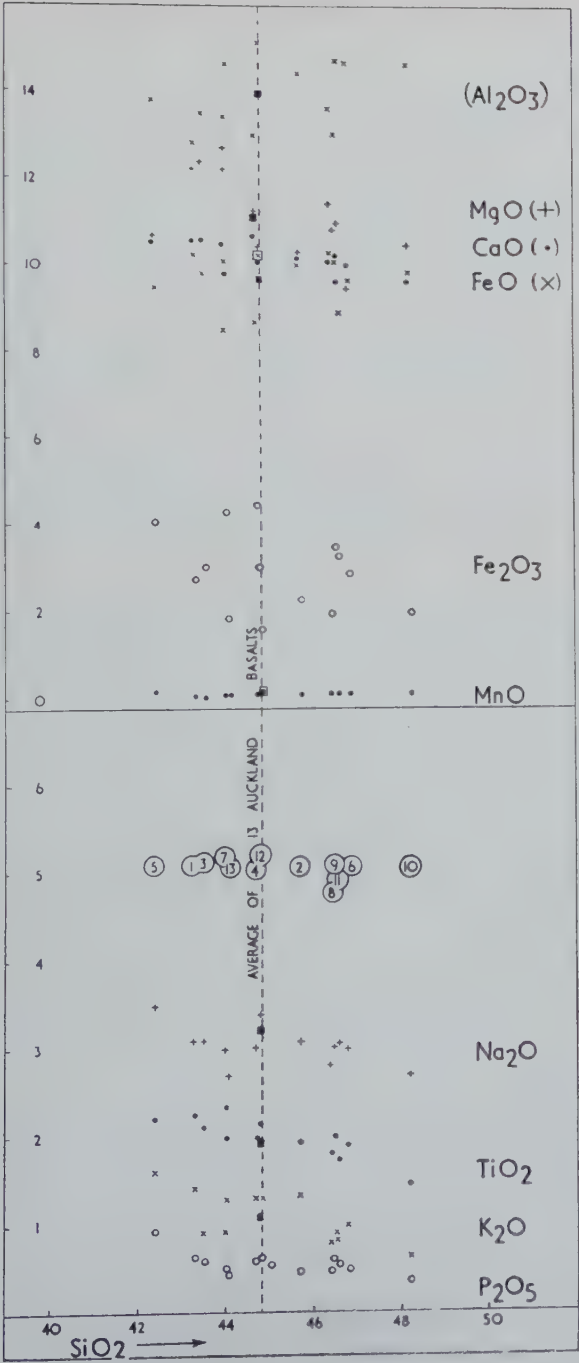
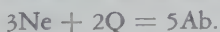


Fig. 1: Variation diagram showing composition of the Auckland basalts. Plots of constituents of the calculated average rock indicated by squares.

TABLE 3: Cations of Unit Cell and Niggli Values of Auckland Basalts

<i>Cations of Unit Cell</i>		1	2	3	4	5	6	7	8	9	10	11	12	13	Ave	Dom
Si	43.4	44.2	43.3	44.2	46	44	45.5	46.7	46.8	46.8	46.8	46.8	45.2	44	44.61	45.4
Ti	1.75	1.4	1.5	1.48	1.62	1.4	1.49	1.35	1.35	1.96	1.04	1.38	1.48	1.7	1.45	2.19
Al	15.2	16.4	16.1	15.6	15.9	17	15.8	15.9	15.3	15.3	16.6	17.5	17.4	16.6	16.23	21.2
Fe ⁺³	2.1	1.7	2.3	3.4	4.8	2.2	3.1	1.48	8.4	2.6	1.56	2.48	1.18	1.4	2.17	1.57
Fe ⁺²	10.7	8.1	8.3	7.3	7.9	7.9	7.1	8.4	8.4	8.4	7.9	7.5	8.2	8.4	7.98	6.21
Mn	0.12	0.1	0.11	0.15	0.17	0.15	0.14	0.14	0.14	0.16	0.14	0.15	0.16	0.14	0.14	0.16
Mg	18.5	14.9	18.4	17.1	15.9	14.2	19.2	17.0	17.0	16.2	14.6	16.0	15.2	18.1	16.53	4.32
Ca	11.6	11.6	11.3	11.5	11.2	10.5	11.5	11.0	11.0	9.3	10.0	10.3	10.7	10.4	10.83	8.29
Na	5.9	5.8	6.1	6.0	6.8	6.1	5.9	5.3	5.3	5.9	5.1	5.8	6.9	5.2	6.15	12.2
K	1.75	1.63	1.15	1.67	2.20	1.2	1.16	1.01	1.01	1.04	0.83	1.3	1.6	1.7	1.37	5.48
P	0.5	1.4	0.5	0.53	0.79	0.42	0.43	0.39	0.39	0.52	0.27	0.47	0.52	0.38	0.46	0.33
<i>Niggli Values</i>																
si	82.5	92.5	83.5	87	89	98	84	93	98	98	101	96	93.5	86	90	117
al	14.4	16	15.5	15	16.8	18.1	15.1	16.2	16.1	16.1	18	17.8	18.1	16.2	16.7	27.4
fm	56.1	52	55.8	55	60.4	51.7	56.2	55.3	57.2	54	54	53.5	51.5	56.5	54	31.2
c	22	24.2	21.8	22	23.7	22.4	22.0	22	19.4	22	22	21.2	22	20.6	21.6	21.2
alk	7.5	7.8	6.9	8	9.1	7.8	6.7	6.5	7.3	7.3	6	7.5	8.4	6.7	7.7	20.2
qz	-47.5	-38.7	-43.8	-43	-47	-33	-42.8	-33	-31	-31	-23	-34	-40.1	-41	-40.8	-62.8
k	0.38	0.27	0.16	0.22	0.23	0.17	0.16	0.16	0.16	0.15	0.14	0.18	0.20	0.32	0.2	0.21
mg	0.62	0.60	0.53	0.61	0.55	0.58	0.65	0.63	0.59	0.61	0.61	0.61	0.61	0.63	0.62	0.53

basalts both of Auckland and of the Waikato district, in South Auckland, was noted by Marshall (1908), although the analyses on which he based his observation appear no longer to be extant. Because of this persistence of normative nepheline he regarded all the basaltic rocks of these areas as basanites. However, except in the case of the unusual differentiate of Auckland Domain, nepheline has no modal expression. Marshall (1908) claimed to be able to detect its presence by microchemical tests and while it may be accepted that his tests did show the presence of sodium ions, it is highly likely that the results were affected by sodium in the glassy mesotaxis rather than by sodium ions in microscopically undetectable modal nepheline. The present writer has examined some hundreds of thin sections cut from the Auckland basalts, and, apart from some sections from the Auckland Domain, to which reference has already been made, he has been unable to identify nepheline in any of them. The occurrence of nepheline in the norm, but not in the mode, of rocks comparable with those of the Auckland field, has often (e.g. Nockolds, 1954, p. 1009) been attributed to the presence of titaniferous augite as the dominant pyroxene, presumably on the grounds that if titania replaces silica in the fabric of the pyroxene then in the calculation of the norm more silica than is shown in the silica account will be available for forming albite, rather than nepheline, by the equation:



In these analyses, however, even if all the titania was contained by the pyroxene, insufficient silica would be freed to balance the account and so avoid the conversion of albite to nepheline. This being so, it is considered more probable that soda, in excess of that required to form the albite molecule of modal feldspar with the silica available, is carried in residual liquors which, after solidification, are represented in the actual rock by a glassy groundmass and by an abundant late stage groundmass feldspar, with undulating extinction, low r.i., and positive figure. Similar material to this last was recognised in Pacific lavas by Cross (1929) and described as plagioclase containing occult carnegieite, and by Bath (1931) as anemousite. MacDonald (1942), however, has shown that in the Hawaiian lavas this mineral contains potassium ions and not occult nepheline molecules and, in consequence, has named it potash oligoclase.

There is no doubt that the rocks under discussion are all undersaturated with respect to silica. Niggli's *qz* parameter (quarzzahl), which measures the availability of silica to satisfy the demands of bases in forming feldspars and ferromagnesians, is consistently negative, with values ranging between —23 and —48. A plot, fig. 2, of Niggli values against the *qz* parameter provides little additional information: increasing deficiency in silica seems to be accompanied by a slight increase in *alk*, by an increase in the ratio of potash to total alkali (*k*) and by a decrease in alumina (*al*). The value *mg* (ratio of magnesia to magnesium and total iron oxides) does not vary significantly, and the same is true of the Niggli value *c* (calcium oxide). It would seem, then, that variation in the degree of undersaturation is essentially due to variations in the proportions of alkali, and particularly of potassium, carried by the rocks.

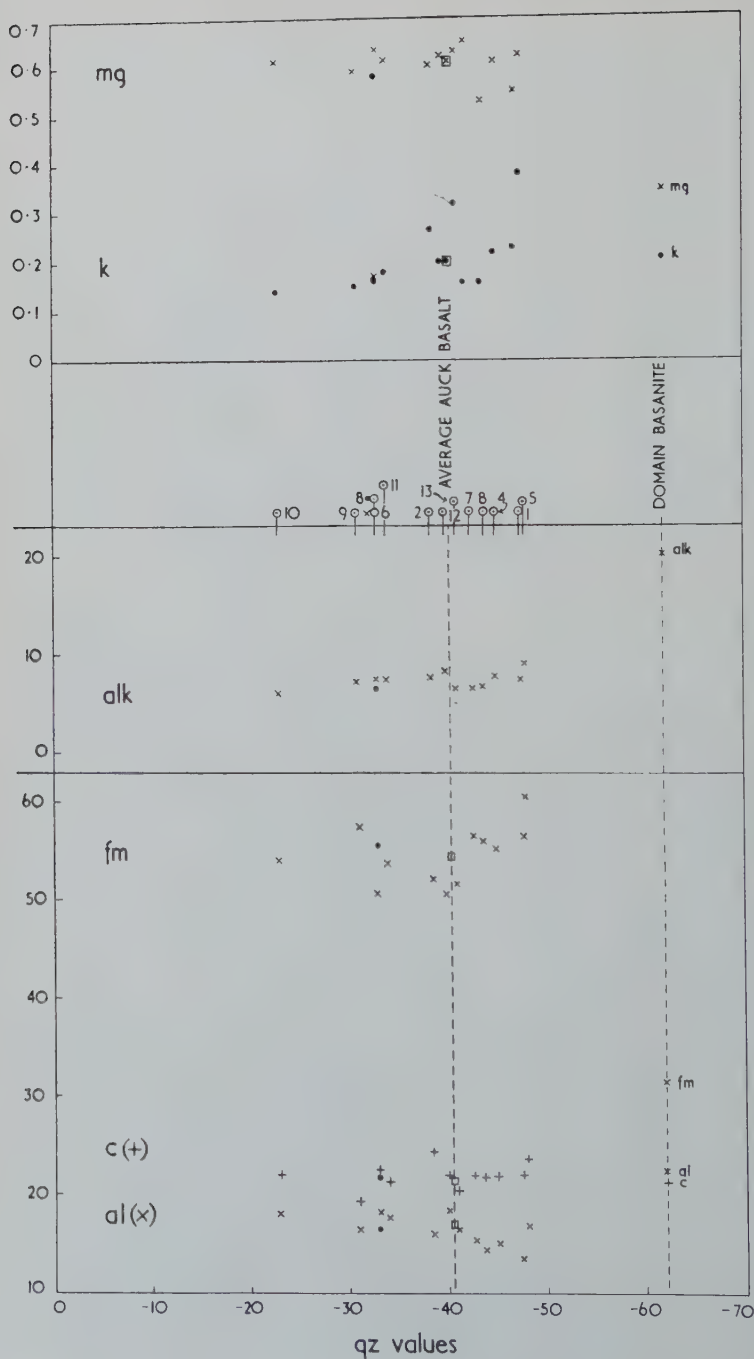


FIG. 2: Variation diagram of Niggli parameters of Auckland basalts.

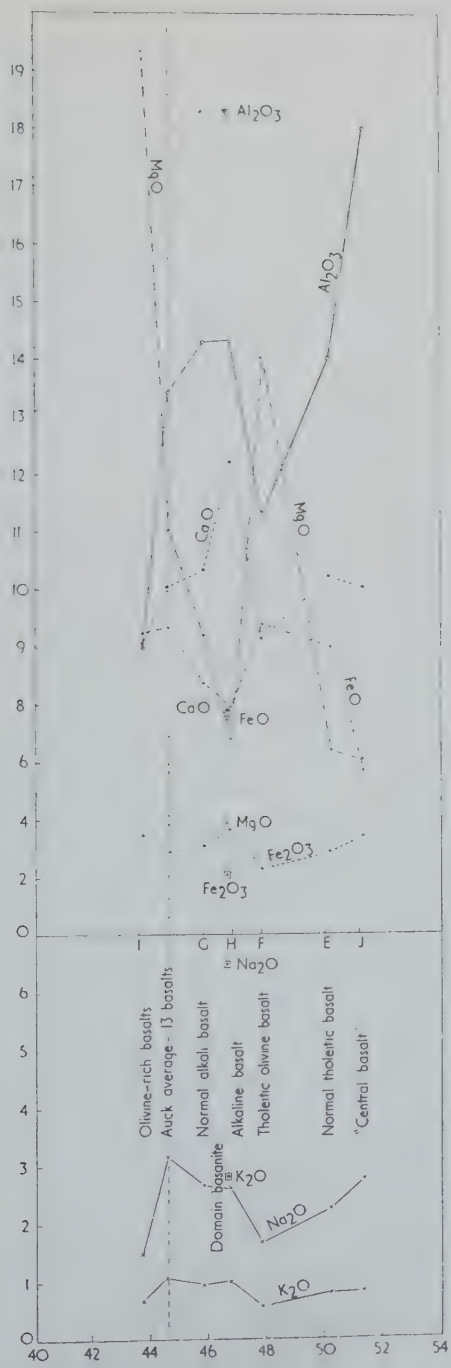


Fig. 3: Variation diagram of Auckland basalts and Nockold's average basaltic types.

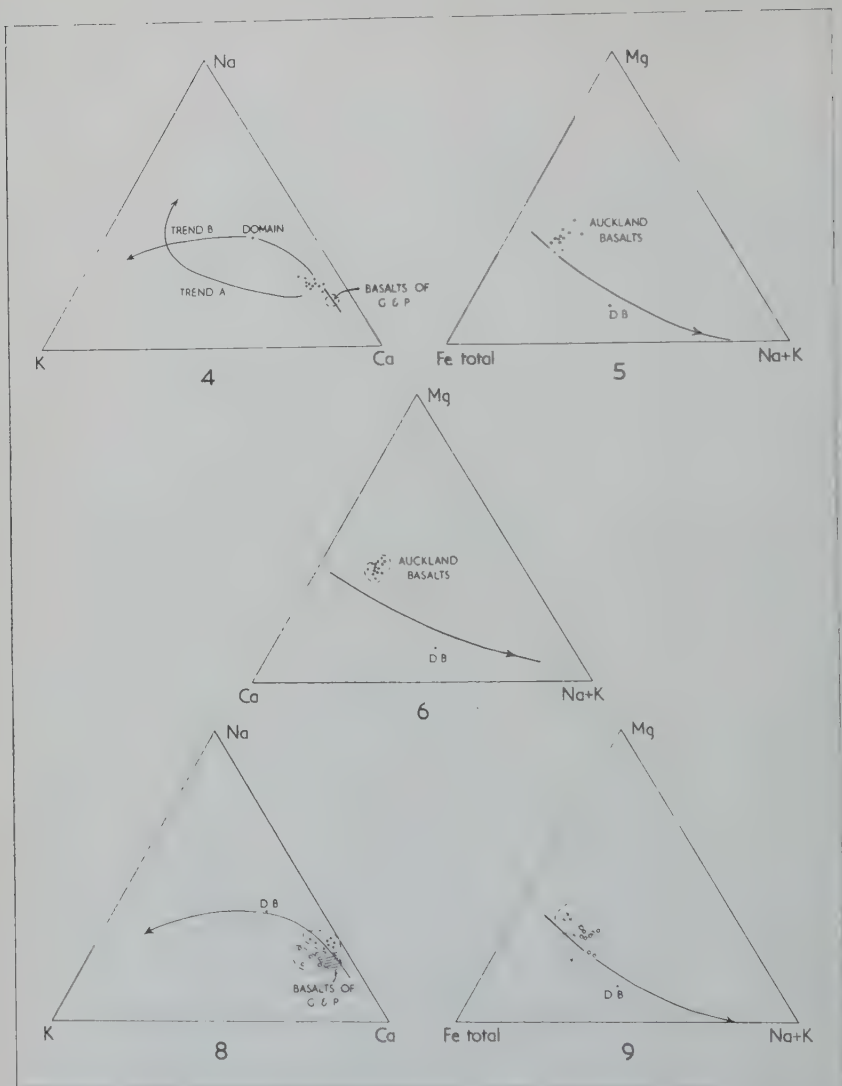


FIG. 4: Ca-Na-K diagram of Auckland basalts showing distribution along Green and Poldervaarts' trend lines.

FIG. 5: Plots of Auckland basalts on Mg-Fe-(Na + K) diagram.

FIG. 6: Mg-Ca-(Na + K) diagram of Auckland basalts.

FIG. 8: Na-K-Ca ternary diagram. Field of basalts of Auckland (ruled); North Auckland basalts (dots); South Auckland basalts (circles); Domain basanite (DB).

FIG. 9: Mg-Fe-(Na + K) diagram. Field of Auckland basalts enclosed by broken line; Northland basalts (circles), South Auckland basalts (crosses), Domain basanite (D.B.).

SEARLE - AUCKLAND BASALTS

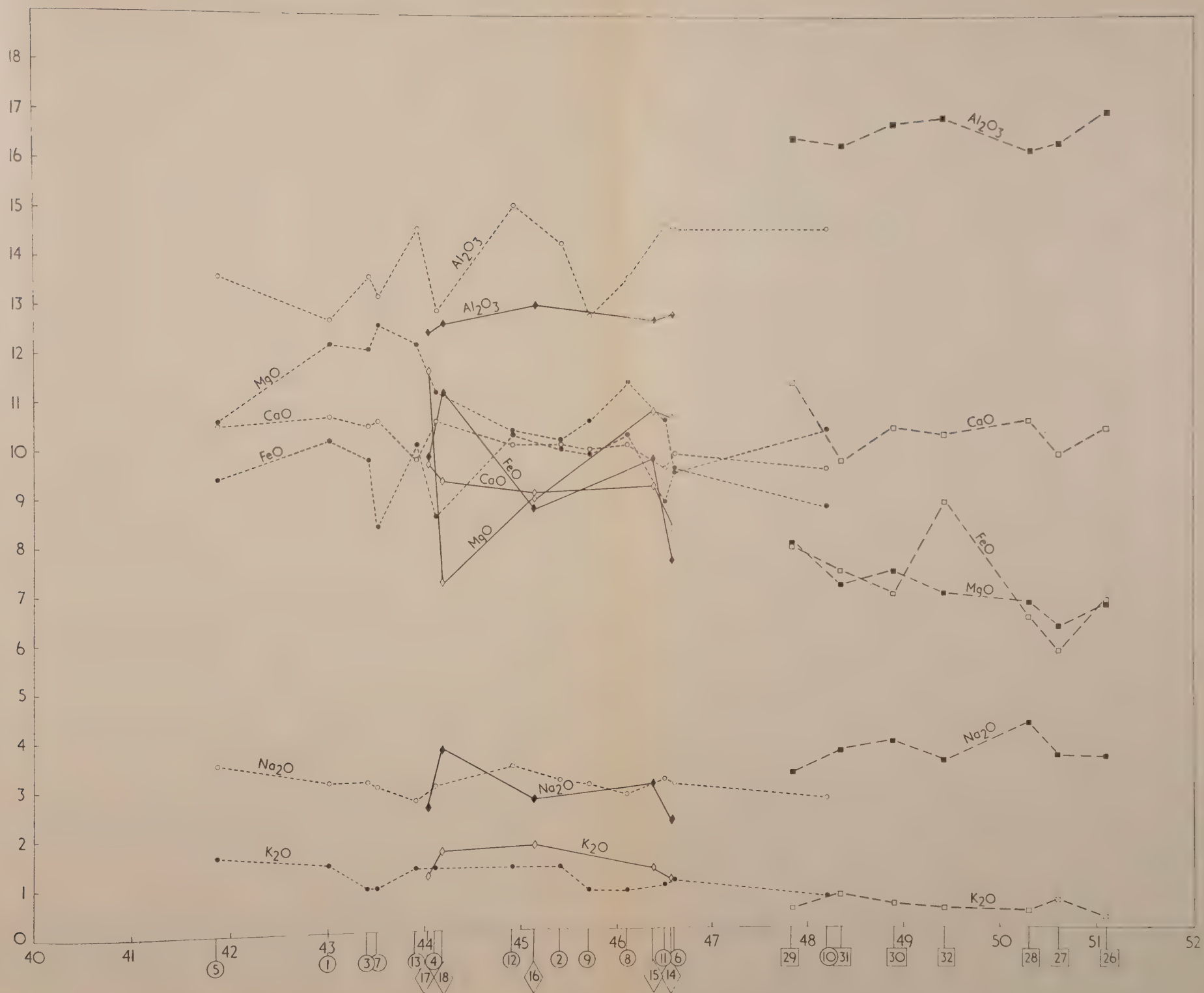


FIG. 7: Variation diagram of basalts of Auckland (circles), Northland (squares), and South Auckland (diamonds).

In the variation diagram, fig. 3, comparison is made of an average Auckland rock, calculated on the basis of the thirteen analyses, with the average chemical compositions of basic volcanic rocks as calculated by Nockold (1954). Whilst Nockold's tables do not provide any indication of the ranges for particular constituents shown by the individual analyses from which the averages were calculated, it would seem that the Auckland rock has a chemical constitution intermediate between that of his "normal alkaline basalt" and that of his "olivine-rich alkaline basalt". The abundant modal olivine which characterises the local lavas would tend to favour its inclusion in the latter group. There are, however, considerable differences between the Auckland analyses and that of Nockold's average olivine-rich alkaline basalt. Firstly, in the Auckland analyses, alumina is always present in excess of magnesia which occurs in amounts substantially equivalent to those of calcium oxide and ferrous oxide. In Nockold's average olivine-rich alkaline basalt, magnesia is twice as abundant by weight as is alumina, whilst this latter is, on par with lime and ferrous oxide. Consequently in the norms of the Auckland rocks there should be a higher proportion of normative anorthite with respect to ferromagnesians than is the case in his average rock. Secondly, in soda, the Auckland basalts are more than twice as rich as Nockold's average rock and this should result in a greater percentage of normative nepheline in the local rocks than in that of Nockold's type. After making due allowance for the fact that his norms are calculated as weight norms whilst those of Table 1 are molecular norms, this does in fact prove to be the case. Again, it would seem likely that the relatively high percentages of nepheline noted in the norms of Table 1, could arise in part, from the moderately high and approximately equal quantities of magnesia and lime. Where magnesia is high and lime is low (as in Nockold's analysis) there is relatively less normative enstatite involved in pyroxene-making according to the equation:



where the total amount of enstatite and ferrosilite is equal to the amount of wollastonite. There is thus more enstatite left to make olivine by the equation:



and hence a relatively greater "pay back" to the silica account from the calculation:



Consequently there will be a smaller deficiency in the silica account to be met by converting albite to nepheline by the equation:



Chemically, then, the lavas of Auckland should be regarded as olivine alkaline basalts. The weight norm calculated by C.I.P.W. methods, and set out below, indicates that the "average" rock is Limbergose but among individual analyses composition varies sufficiently to cause some of the rocks to

fall into other subrangs (e.g. Papernose and Anvergnose) of the C.I.P.W. taxonomy.

or	6.67	
ab	12.58	47.22
ne	7.95	
an	20.02	
wo	11.40	
en	9.64	
fs	2.94	
fo	14.14	52.8
fa	7.34	
mt	4.18	
il	1.82	
ap	1.34	

Class III, 1; order 6, 1, rang 3, subrang 4 (Limbergose).

The mineral assemblages, chemical composition and the prevailing pegmatoid fabric of the Auckland Domain basanite, clearly suggest that this nepheline-bearing rock has crystallised from an alkaline residual liquid which has developed by crystallisation-differentiation of apparent basic magma. Occurring as it does, in sporadic blocks making up only a small and localised part of the tuff and pyroclastic accumulations surrounding one of the many nests of eruptive centres of the Auckland field, its occurrence is most readily explained as a late differentiate of the more typical alkali basalt that has solidified and subsequently been disrupted and ejected by eruption from one of the minor and later vents.

It is noteworthy that, in lavas that are more typical of the area, there are occasional small "inclusions" with indistinct boundaries which possess marked pegmatoid texture and have a groundmass of potash oligoclase. In some instances these small pegmatoid masses are in the form of irregular and discontinuous veins or lenses and appear to be most satisfactorily explained as small concentrations of residual fluid, streaked out as if by flow banding. Similar texture has been observed (Searle, 1958) in veins of lava which have been squeezed into shrinkage cracks of carbonised wood. It is suggested that a somewhat similar type of filter-press fractionation on a large scale could well have been responsible for the differentiation of the Domain basanite.

The petrochemistry of the rocks is in accord with this suggestion. From the earlier tables it will be seen that whereas the Domain rock, on analysis, has a silica content (46.66%) higher than the calculated average (44.8%), it is notably more undersaturated with respect to silica than is the latter. The *qz* value of the basanite is — 62.8 while that of the calculated average is — 40.8. This large discrepancy between the total silica and that

necessary to form feldspars and pyroxene with the bases available stems from the relatively high alkali content (*alk* of Domain rock is 20.2 as compared with *alk* = 7.7 for the average) and the correspondingly small proportion made up of the ferromagnesian elements (*fm* = 31.2 for Domain and *fm* = 5.4 for the average). The ratios of potash to total alkali show no significant variation (0.21 and 0.20 respectively) in the two rocks but the value *mg*, defining ratio of magnesia to magnesia and total iron oxide, is markedly lower in the basanite. If this rock has indeed been formed by fractionation from a parent magma comparable in composition to the Auckland "average" basalt then the process has largely involved loss from the latter of femic in excess of salic constituents; and in the case of the femic constituents of magnesium in excess of iron. The obvious explanation that suggests itself is the separation from such a magma of olivine and diopsidic pyroxene, leaving a residual magma enriched in silica, alumina and alkalies and with relative enrichment in iron in the resulting femic fraction.

Considering the approximately equal volumes of a unit cell of 160 oxygen atoms the profit and loss account of cations at a locus of exchange would be as follows:

Cations	Lost	Gained
Si		1.2
Ti		0.74
Al		4.97
Fe ⁺³	0.6	
Fe ⁺²	1.79	
Mg	12.21	
Ca	2.54	
Na		6.05
K		2.11
P	0.13	

Such an exchange involves a loss of 35.63 valencies and a gain of 30.73 which is sufficiently close to show that some magma close to that of the Auckland average in composition could be the parent of the basanite. The loss of calcium ions adds weight to the suggestion that diopsidic pyroxene as well as olivine would be involved in the primary crystal fractionation. When examined in this way it is clear that the major loss to the magma, apart from elements that may have been removed in stoichiometric proportions, is that of magnesium ions, and that only about 12% of the total cations of the system are mobilised in effecting the change.

In fig. 4, a ternary diagram showing the relative number of ions of Na-K-Ca in the basalts of Auckland, it will be noticed that both the average basalt and the Domain basanite lie on trend 'B' of Green and Poldervaart (1958) — the basalt-andesite-dacite-rhyolite line which may be considered characteristic of continental areas; Green and Poldervaart's plot of typical basalts is also shown. The relative positions of the three rock types in the plot suggests that the process which may have led to the formation of Domain basanite from local basaltic magma may in fact be the further extension of a process by which the Auckland alkaline basalts themselves had already moved from a more primitive basaltic parent. Plots are also given (figs. 5 and 6) of Mg-Fe-(Na + K) and Mg-Ca-(Na + K), which Green and Poldervaart (1954) regard as the most suitable diagram for showing chemical

variation in igneous rock series since they show most scatter of plots; again, the plots show a similar distribution along the recognised trend lines of those writers.

In the Auckland province, late Pleistocene and Recent basaltic eruptions have not been confined to the region in the immediate neighbourhood of Auckland city. There has been a further concentration of activity both in Northland, near and north of Whangarei, and in the south of the province, in the Waikato district. It is probable, as is generally recognised, that vulcanicity in these latter areas was a little earlier than it was on and about the isthmus.

There is no evidence in the vicinity of Auckland of volcanic activity in the interval between the exceedingly widespread and vigorous mid-Tertiary andesite eruptions, that were responsible for the formation of the massive boulder and tuff deposits of the Manukau Breccia formation of the Waitemata Group, and the late-Pleistocene—Recent episode of vulcanicity that formed the cones and flows of the isthmus. Elsewhere in the province, however, volcanoes were active. Turner and Verhoogen (1951, p. 150–1), following Benson (1941), recognise an Auckland Tertiary petrological province characterised by calc-alkaline andesite-dacite-rhyolite association of rocks "identical with the typical volcanic series of fold-mountain arcs" with, in the northern sector, Pliocene–Pleistocene eruptions producing "somewhat alkaline basalts with which nepheline-theralite pegmatoid is associated in one instance". They suggest, and the writer would concur, that this latter activity in the north, which includes that of late Pleistocene and Recent times in the vicinity of Auckland, may indicate the initiation of a new petrographic province. In the south of Auckland province, still active volcanoes and those of Pleistocene times are andesitic, in contrast with those of the north which they claim have chemical characteristics similar to those of oceanic olivine basalt.

In the variation diagram, fig. 7, the compositions of the basalts of Auckland isthmus are compared with those of North Auckland (Kerikeri Series) and with those of South Auckland (analyses from: Ferrar, 1925; Henderson and Grange, 1926). It will be observed that, whilst each group has its own characteristic features, the Auckland rocks have more in common with those of South Auckland than they have with the basalts of Northland. Attention is directed to the following points:

- (1) The rocks of Northland are uniformly more siliceous (SiO_2 ranging between 47.8 per cent and 51.1 per cent) than those of Auckland, except for that of a flow from One Tree Hill. On the other hand, whereas the silica percentages of the Auckland rocks range over the limits shown by analyses from South Auckland, more than one-third of the former are more basic than any of the latter.
- (2) Alumina is the next most important constituent in all three areas but the Northland rocks are much more highly aluminous than are those of the other two groups.
- (3) The Auckland and South Auckland analyses are alike in that they show magnesia, lime and ferrous oxide in subequal amounts with magnesia usually slightly in excess. In the northern rocks, however, lime is always dominant and the magnesia decidedly depressed.

- (4) Again, in the case of soda and potash there is considerable similarity between the rocks of Auckland and South Auckland, although in rocks of the southern district the ratio of potash to soda is generally higher than in those of Auckland. In the northern rocks, the total alkali is not greatly different from that in the others but potash is relatively of much less importance.

Na-K-Ca and Fe-Mg-(Na + K) plots of the basalts from the three areas are given in the ternary diagrams of fig. 8 and fig. 9. In both cases the Northland rocks are located on the general trend line of Green and Poldervaart (1958), intermediate in position between the Auckland basalts and the Domain basanite. The plots of the South Auckland basalts in the Na-K-Ca diagram lie close to those of Auckland but on the potassic side, and in the Fe-Mg-(Na + K) diagram several fall within the field of the Auckland rocks. These diagrams draw attention to the fundamental similarities between the rocks of Auckland and Northland. The occurrence of basalts relatively rich in alumina and lime, in a district where the dominant older rocks are calcareous mudstones is highly suggestive of modification of basic magma by the assimilation of calcium and aluminium. Conversely, the low calcium content of the Auckland basalt tends to suggest the absence of early Tertiary calcareous sediments from the succession which the field evidence indicates is probably the case.

Of some interest is the occurrence of olivine nodules in the tuff accumulations associated with the explosion craters of North Shore. At Onepoto Basin and Tank Farm these are abundant and range in size up to approximately 1 in. in diameter; in the tuff and lapilli tuff of Pupuke they are also common though smaller in size. Turner and Bartrum (1929) provide the following analysis, by F. T. Seelye, of nodules collected along the west shore of the fresh water Lake Pupuke:

SiO ₂	41.53
TiO ₂	0.08
Al ₂ O ₃	0.42
Fe ₂ O ₃	0.10
Cr ₂ O ₃	0.20
V ₂ O ₃	nil
FeO	8.51
MnO	0.15
NiO	0.44
CoO	0.05
MgO	47.33
CaO	0.31
BaO	nil
SrO	nil
Na ₂ O	0.11
K ₂ O	nil
H ₂ O +	0.24
—	0.21
S	0.02
P ₂ O ₅	tr
CO ₂	nil
	99.70

The fact that the debris containing these nodules has been ejected by mainly phreatic explosions and that, particularly in the case of Onepoto and

Tank Farm volcanoes, it contains a very large proportion of accidental material, definitely points to their derivation from the upper part of the parent magma body. It seems highly probable that they represent early crystallised fractions of the magma which have separated as marginal segregations over the magma body. That they could so have been formed by the concentration of relatively few elements in localised centres of segregation is suggested by preparing a profit and loss account for a standard cell of averaged Auckland basalt compared with that of the nodules.

Ions	Gain by cell	Loss from "average" cell
Si		3.91
Ti		1.6
Al		15.75
R ³		1.98
R ²	0.08	
Mg	52.93	
Ca		10.53
Na		6.05
K		1.37
P		0.46
Total valencies	106	105

The picture presented is obviously oversimplified but nevertheless it is clear that from an ionic point of view all that is involved is an inward migration of magnesium ions to loci of crystallisation and a consequent loss by exclusion of other cations other than silica. With regard to trace elements there is a much greater concentration of nickel and to a less extent of chromium in the nodules than in the basalt; chromite occurs as an accessory mineral in some of the nodules examined.

Various suggestions have from time to time been advanced to explain the origin of such segregations. They have been regarded as exogenous xenoliths carried up by magma from the depths (e.g. Ernst, 1935; Ross, Foster and Myers, 1954) and as endogenous aggregates of early fractionated minerals that have settled in the magma (and so been concentrated) later brought up by convection (e.g. Jaeger and Joplin, 1955). Their constant association elsewhere with olivine and nepheline basalts points to a local origin (Turner and Verhoogen, 1951, p. 140) and in the present instance the field evidence is definitely in favour of a local and fairly superficial source. Comparable segregations are not commonly found in the basalts of the Auckland field. They are most prolific in the lavas of the Devonport volcanoes, not far distant from the explosive centres that supplied the nodules. It is perhaps significant that segregations of the pegmatoid type already referred to are particularly common in the lavas of Takapuna emanating from the Pupuke volcano. In these segregations coarse titaniferous augite, sometimes bordered with aegarine augite, together with acicular or stringy olivine and abundant ilmenite and apatite are inset in a groundmass of ?potash oligoclase. It may well be that these small masses represent local patches of residual fluid from which olivine and other minerals of the nodules have already crystallised. Certainly their mineralogy suggests enrichment in the very elements which would be rejected in the formation of the nodules.

Finally, it will be noted that the analyses of the Auckland lavas, particularly in respect of their high normative nepheline, and the absence in them of modal nepheline, show marked resemblance to those of many of the basanoid, ankaramite and picrite-basalt, alkali-rich sub-aluminous associations of the Pacific basin, for which rocks Bath (1930; 1931) suggested the name pacificite. Turner and Verhoogen (1951, p. 151) have already drawn attention to this affinity of the oceanic olivine basaltic rocks with those of Banks Peninsula (Pliocene), east Otago (Pliocene) and Auckland (Pliocene-Pleistocene) provinces of the continental area of New Zealand. The Dunedin area suffered orogeny in Pliocene times but has been tectonically stable since then (Cotton, 1957). Benson (1941) connects the differentiation of the alkaline magma of this province with the moderate tectonic deformation which occurred during, and reached its climax soon after the time of its eruption.

The North Auckland region has also been seismically stable during Pleistocene times (Eiby, 1955) and probably, as may be inferred from the studies of Brothers (1954), has been stable from well back in the Pliocene. This region of Pliocene-Pleistocene stability probably includes the whole of the area north of Manukau Harbour, i.e., north of the inferred Manukau fault which delimits the foundered block of the Manukau lowlands that existed as a basin of sedimentation from early Pliocene times. Movement along the fault began in post-Altonian and pre-Opoitian times and it may be that the rise of magma occurred along this zone of fracture, or, as is more likely, through fractures in the scattered undermass of the foundered block, for volcanoes in age contemporary with or slightly older than those of the isthmus are found over the whole of its extent.

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THE NEW ZEALAND PRIMARY GRAVITY NETWORK

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Summary

Between 1947 and 1955 the Department of Scientific and Industrial Research established the New Zealand Primary Gravity Network, a set of 437 control points for gravity observations in the North and South Islands of New Zealand. The gravity differences between nineteen stations were measured with the Cambridge pendulum apparatus, and between all stations with a North American gravity meter. Initially the network observations were reduced separately in the North and South Islands; the resulting gravity values constitute the New Zealand Provisional System, which has remained the basis for recording gravity results within New Zealand. Subsequent adjustment of the network, both to make it internally consistent and to bring it into agreement with the first order world network based on Potsdam, has resulted in a revised set of values of gravity, which constitute the New Zealand Potsdam System (1959), and which differ by an average of $+5.0$ mgal from the New Zealand Provisional System values. Values of gravity and of free air and Bouguer anomalies are given for the 437 network stations.

INTRODUCTION

A large part of our knowledge of the earth's external form and internal structure is based on measurements of the force of gravity. Since 1930 an increasing quantity of gravity data has been obtained by using modern gravity meters. Although geodetic gravity meters are capable of directly measuring gravity differences throughout the world, the most numerous and accurate observations are made with instruments with a range of about 100 mgal and a precision approaching 0.01 mgal, or 1 part in 10^8 of the earth's field. The scale factor of the gravity meter must first be accurately determined, preferably by comparison with pendulum observations; the value of gravity at any point is then found by measuring the change of gravity from a control point at which the value is known. Since these control points must be frequently reoccupied to determine the drift of the gravity meter, there should be a sufficient number suitably distributed throughout the country in order to eliminate unnecessary travelling; and to ensure that gravity observations in different parts of the country are reduced to a common basis, the values of gravity at all control points should be accurately determined.

TABLE 1—Adjustability a as a function of the difference between the two estimates of the gravity difference $|\Delta_{2g} - \Delta_{1g}|$

$|\Delta_{2g} - \Delta_{1g}|$ (mgal)	.....	.....	.....	a
0.00-0.03	.....	.....	.....	1
0.04-0.06	.....	.....	.....	2
0.07-0.10	.....	.....	.....	4
0.11-0.15	.....	.....	.....	7
0.16-0.20	.....	.....	.....	11
0.21-0.25	.....	.....	.....	16
0.26-0.30	.....	.....	.....	22

In 1947 the Department of Scientific and Industrial Research began the establishment of the New Zealand Primary Gravity Network to provide such a system of gravity control points, and also to obtain a representative set of values of gravity and of gravity anomalies throughout New Zealand. In 1947-48, H. W. Robertson and R. A. Garrick (1960) measured gravity differences with the Cambridge pendulum apparatus between a base station at Wellington and eighteen other stations throughout the country, and between New Zealand and Cambridge, England. Between 1949 and 1955 an additional 418 stations were established using a North American gravity meter, and since 1950 Professor G. P. Woollard of the University of Wisconsin and his collaborators have made a number of measurements of the gravity difference between New Zealand and Washington, U.S.A., with both Worden gravity meters and Gulf pendulum apparatus.

The diversion of the North American gravity meter to local surveys prevented the establishment of the network being carried on continuously, and at the same time, the need for a reference basis for these surveys necessitated the reduction and adjustment of the network observations in stages. This reduction was based on the Cambridge pendulum observations, and the resulting set of values of gravity assigned to the network stations constitutes the New Zealand Provisional System, which remains the basis for recording gravity results within New Zealand. Since the completion of this preliminary reduction, the values of gravity at the network stations have been further adjusted by unifying the North and South Island parts of the network, by a more rigorous calibration of the gravity meter by means of the Cambridge pendulum observations, and by revising the New Zealand gravity datum on the basis of the recent measurements linking New Zealand to Washington. The set of values resulting from this adjustment constitutes the New Zealand Potsdam System (1959). These values of gravity at the 437 stations of the Primary Gravity Network are listed in appendix A, together with the corresponding values of the free air and Bouguer anomalies.

ESTABLISHMENT OF THE PRIMARY GRAVITY NETWORK

The locations of the 418 gravity meter and 19 pendulum stations of the Primary Gravity Network are shown in figs. 1 and 2, and their geographic coordinates are listed in the tables of appendix A*. The gravity meter stations

*Detailed diagrams of all network stations are available on request from the Geophysics Division, Department of Scientific and Industrial Research, Wellington.

are spaced about 25 km apart along the main roads in the North and South Islands of New Zealand, and most can be occupied with a vehicle-mounted instrument.

The North American Gravity Meter AGI 96 was used to measure the gravity differences between the network stations. During the measurements the stability of the instrument was checked periodically over calibration ranges at Wellington (about 30 mgal) and Christchurch (about 70 mgal) for the North and South Islands respectively.

Differences between the force of gravity at successive stations were measured by the "looping" method (Nettleton, 1940), which enables instrumental drift and tidal variation to be eliminated, leaving two independent estimates of the difference, $\Delta_1 g$ and $\Delta_2 g$. From these the mean gravity difference:

$$\Delta g = \frac{1}{2} (\Delta_1 g + \Delta_2 g)$$

and a measure of the accuracy of the mean $|\Delta_2 g - \Delta_1 g|$ were obtained. Most of these measurements go to form networks of polygons, or closed circuits (figs. 3 and 4), whose sides include two or more stations.

North Island Network

Field work in the North Island continued from March to October 1949; gravity differences between 234 gravity meter and 10 pendulum stations were measured with the North American gravity meter. The maker's value of the scale factor, 0.09444 mgal per scale division, was used for the preliminary computation of the results. The closure errors for the various circuits shown in fig. 3 were distributed by the method of least squares, the iterative method of Gibson (1941) being used for the solution of the normal equations. For this adjustment, each observed gravity difference between successive stations was assigned an "adjustability" a , or reciprocal weight, which depends on the difference between the two estimates of the gravity difference $|\Delta_2 g - \Delta_1 g|$, as shown in table 1. The total adjustability of a circuit side is given by the sum of the adjustabilities corresponding to its component differences: in fig. 3 the total adjustability for each side is shown above the line, with the correction (in mgal) to be applied to the total measured difference along each side shown beneath the line. This correction is distributed amongst the component differences in proportion to the adjustability of each.

A preliminary comparison between the values of gravity at the ten pendulum stations, derived from these adjusted gravity meter measurements, and the corresponding values obtained with Cambridge pendulum apparatus, showed that the maker's scale factor for the gravity meter was too high, and that a revised value of 0.09396 mgal per scale division should be adopted. The Cambridge pendulum value * at the pendulum station *LOWER HUTT* (980 289.5 mgal) was chosen as the datum for the North Island Network. Values of gravity (g_1) based on this datum and the revised value of the scale factor constitute the North Island part of the New Zealand Provisional System. Values of g_1 for the pendulum stations are given in table 2.

*Obtained by Robertson and Garrick (1960) and based on Cambridge 981 265.0 mgal (Bullard and Jolly, 1936).

TABLE 2—Values of gravity (in mgal) at the nineteen pendulum stations of the New Zealand Primary Gravity Network

Station	g_1	g_2	g_c	δg_c	g_3	g_4
North Island						
P1 AUCKLAND ..	979 943.79	979 943.79	979 943.3	+0.25	979 943.55	979 948.59
P2 DOUBTFULLESS BAY ..	979 796.17	979 796.17	979 796.4	-0.40	979 796.00	979 801.04
P3 HASTINGS ..	980 084.07	980 084.07	980 083.6	+0.17	980 083.77	980 088.81
P4 LOWER HUTT ..	980 289.50	980 289.50	980 289.5	-0.39	980 289.11	980 294.15
P5 OPOTIKI ..	980 004.05	980 004.05	980 003.2	+0.59	980 003.79	980 008.83
P6 ROTORUA ..	979 963.19	979 963.19	979 962.6	+0.34	979 962.94	979 967.98
P7 RUSSELL ..	979 820.06	979 820.06	979 820.7	-0.82	979 819.88	979 824.92
P8 TE ARAROA ..	979 907.92	979 907.92	979 907.0	+0.70	979 907.70	979 912.74
P9 WELLINGTON ..	980 261.41	980 261.41	980 261.8	-0.77	980 261.03	980 266.07
P10 WHANGAMONGA ..	980 074.03	980 074.03	980 072.8	+0.94	980 073.74	980 078.78
South Island						
P11 CHRISTCHURCH A ..	980 504.28	980 504.95	980 504.6	-0.14	980 504.46	980 509.50
P12 CHRISTCHURCH ..	980 504.49	980 505.16	980 504.1	+0.57	980 504.67	980 509.71
P13 DUNEDIN ..	980 737.84	980 738.25	980 737.0	+0.66	980 737.66	980 742.70
P14 HOKITIKA ..	980 407.15	980 407.93	980 408.1	-0.62	980 407.48	980 412.53
P15 KAIKOURA ..	980 373.22	980 374.04	980 373.5	+0.10	980 373.60	980 378.64
P16 MONOWAI ..	980 647.61	980 648.12	980 647.7	-0.13	980 647.57	980 652.61
P17 MT. COOK ..	980 265.18	980 266.11	980 267.3	-1.57	980 265.73	980 270.77
P18 QUEENSTOWN ..	980 499.16	980 499.84	980 499.5	-0.15	980 499.35	980 504.39
P19 TAKAKA ..	980 270.40	980 271.33	980 270.4	+0.55	980 270.95	980 275.99

g_1 New Zealand Provisional System
 g_2 Unified network values
 g_3 Revised network values
 g_4 New Zealand Potsdam System (1959)
 g_c Cambridge pendulum values (based on Cambridge 981
265.0 mgal)
 δg_c Corrections to the Cambridge pendulum values

South Island Network (Northern Section)

After completing the observations in the North Island the diversion of the gravity meter to local surveys in the volcanic region and elsewhere in the North Island delayed the start of work in the South Island until December 1952. Observations of the gravity differences between 98 gravity meter and 5 pendulum stations continued until May 1953, when the gravity meter was again diverted to local surveys in the North Island.

The northern section of the South Island Network (fig. 4) was adjusted by distribution of circuit closure errors as described above for the North Island. In the period between the end of the North Island observations and the beginning of work in the South Island, the gravity meter had been damaged and repaired; a new value for the instrument scale factor of 0.0933 mgal per scale division was derived from observations on the Wellington and Christchurch calibration ranges and also from a comparison of the gravity meter and Cambridge pendulum values at the five pendulum stations. The pendulum station *TAKAKA* was chosen as the datum point for the South Island Network, and the Cambridge pendulum value 980 270.4 mgal adopted. Values of gravity (g_1) at the stations of the northern section of the South Island Network based on this scale factor and datum form part of the New Zealand Provisional System; values of g_1 for the pendulum stations are listed in table 2.

South Island Network (Southern Section)

Work was resumed on the South Island Network in November 1954, and continued until completion in May 1955. The gravity meter had again been damaged and repaired, and a new scale factor, 0.0937 mgal per scale division*, was determined by comparison of observations of the Christchurch calibration range before and after the change. The observed gravity differences between the 88 gravity meter and 4 pendulum stations were adjusted by the method of least squares as before (fig. 4). The southern section was connected to the northern section at the gravity meter stations *Lyndon* and *Templeton*, the adjusted gravity difference between these two being taken as that derived from the adjustment of the northern section. The values of gravity (g_1) calculated for the southern section with the scale factor 0.0937 form a homogeneous set with those of the northern section, the whole constituting the South Island part of the New Zealand Provisional System.

NEW ZEALAND POTSDAM SYSTEM (1959)

The New Zealand Provisional System was adopted to meet the needs of local and detailed gravity surveys being made concurrently with the establishment of the network. When the network had been completed, it was

*Results which are based on this factor are equivalent to those obtained in the Northern Section using the factor 0.0933 mgal per scale division.

obviously desirable to adjust the network values as a whole, and to derive the best set of values in the internationally accepted Potsdam System. Three further steps were required: firstly, to unify the North and South Island Networks by a gravity meter connection between the two islands; secondly, to calibrate the gravity meter more rigorously by means of the Cambridge pendulum observations; and thirdly, to adjust the datum of the New Zealand gravity values on the basis of all recent international connections. The resulting set of values of gravity at the Primary Gravity Network stations defines the New Zealand Potsdam System (1959).

Unification of the North and South Island Networks

The North and South Island Networks were connected by measuring with Worden gravity meters the gravity difference between the pendulum stations *LOWER HUTT* and *CHRISTCHURCH A* (Professor G. P. Woollard, pers. comm.; see table 3). A least-squares fit of the New Zealand Provisional System values (g_1) at seven North Island stations (in the vicinity of Auckland, Hastings, and Wellington) to Woollard's corresponding values showed a discrepancy of $(0.64 \pm 0.10) \times 10^{-3}$ between the calibration of the North American gravity meter and the Worden gravity meters; accordingly the value of 215.45 mgal for the gravity difference between *CHRISTCHURCH A* and *LOWER HUTT* was derived as the equivalent in the New Zealand Provisional System to Woollard's value 215.31 mgal.

TABLE 3—Gravity Meter Observations of the Difference between
CHRISTCHURCH A and *LOWER HUTT*

Year	Observer	Worden Meter	Δg (mgal)
1950	Muckenfuss	10e	215.5
1954	Bonini	10f	215.2
1954	Bonini	147	215.1
1957	Rose	10f	215.45

Mean 215.31 ± 0.10

Further measurements of the relative values of the Wellington and Christchurch calibration ranges revealed that the previously adopted values of the scale factors used in the South Island were 0.1% too large relative to the factor used in the North Island; on this account they were reduced to 0.0932 mgal/scale division for the northern section, and 0.0936 for the southern section, to correspond to the factor of 0.09396 for the North Island.

By adopting these values for the South Island scale factors, and 215.45 mgal for the difference between *CHRISTCHURCH A* and *LOWER HUTT*, the South Island gravity values were made consistent with those in the North Island, resulting in a unified network based on *LOWER HUTT*.

*Where a numerical value in this paper is shown in the form $x \pm h$, h is the standard error of x .

as datum point. The transformations converting the gravity values (g_1) in the New Zealand Provision System to the values (g_2) for the unified network may be expressed as follows:

North Island

$$g_2 = g_1$$

South Island

$$g_2 = g_1 + (2.32 - 0.0011 (g_1 - 979\ 000))$$

Calibration of the Gravity Meter by means of Cambridge Pendulum Observations

The correction to the adopted calibration of the North American gravity meter was found by fitting the unified network values g_2 to the Cambridge pendulum values g_c by the method of least squares, a procedure similar to that followed by Kneissl (1956) in adjusting the Preliminary European Network. The solution of the normal equations gave the following results for the mean value of g_2 , 980 232.96 mgal.

Calibration correction factor $-(0.45 \pm 0.56) \times 10^{-3}$

Correction to datum $-(0.35 \pm 0.15)$ mgal

Hence the revised network values (g_3) may be derived from the unified network values (g_2) by the transformation:

$$g_3 = g_2 + (0.20 - 0.00045 (g_2 - 979\ 000))$$

The Cambridge pendulum values g_c (based on Cambridge 981 265.0 mgal), the pendulum residuals δg_c , and the revised network values g_3 for the nineteen pendulum stations are shown in table 2.

The calibration correction, $-(0.64 \pm 0.10) \times 10^{-3}$, derived by comparison with Woollard's North Island values, and the correction, $-(0.45 \pm 0.56) \times 10^{-3}$, found from all New Zealand Cambridge pendulum observations are not significantly different. Therefore, on the basis of New Zealand measurements, there is no evidence for the discrepancy between the calibration of Woollard's Worden meters and the Cambridge pendulum apparatus of the order of 1×10^{-3} claimed by Cook (1957).

New Zealand Datum in the Potsdam System

In recent years the International Association of Geodesy has established a first order world network of gravity stations (Coron, 1956), through which all national gravity networks can be connected to each other and to the international reference point at Potsdam, at which the conventional value of gravity is 981 274.00 mgal (Rieckmann and German, 1957). The world network station for New Zealand is the Primary Gravity Network station *CHRISTCHURCH A*, at which the value of gravity has been determined in recent years by Cambridge pendulum apparatus, Gulf pendulum apparatus, and Worden gravity meters (table 4).

TABLE 4—Determinations of the Value of Gravity at *CHRISTCHURCH A*

Year	Observer	Apparatus	g mgal	Base Value Cambridge
(1) 1947-48	Robertson and Garrick	Cambridge Pendulum	980 508.1	$g = 981\ 268.5$
(2) 1950	Muckenfuss	Worden 10e	980 509.4	Washington D.C. Commerce Base floor $g = 980\ 119.2$
(3) 1954	Bonini	Worden 10f	980 509.4	
(4) 1954	Bonini	Worden 147	980 509.6	
(5) 1957	Rose	Worden 10f	980 509.7	
			508.8	
(6) 1956-57	Rose	Gulf Pendulum	980 509.2 (mean of 4 observations)	$g = 980\ 119.2$
(7) 1958	Iverson	Gulf Pendulum	980 508.2 (poor closure)	

Of the New Zealand to Washington observations, (7) is derived from a set with large closure errors (J. C. Rose, pers. comm.) and has accordingly been discarded; the remainder, (2) to (6), form a consistent set giving a mean value for *CHRISTCHURCH A* of $980\ 509.47 \pm 0.10$ mgal (with double weight arbitrarily assigned to observation 6).

The Cambridge pendulum value is about 1.4 mgal less than this figure, and from Robertson and Garrick's (1960) data, has a standard error of 1.2 mgal. However the correction to the pendulum value at *CHRISTCHURCH A* (δg_c in table 2), derived by the comparison of the gravity meter values with all nineteen Cambridge pendulum observations in New Zealand, is only $+ (0.14 \pm 0.21)$ mgal; this would suggest that the source of the discrepancy of 1.4 mgal between the Cambridge pendulum and Woollard's observations lies in measurements outside New Zealand. Since neither Woollard's observations between *CHRISTCHURCH A* and Washington, nor those of Cook (1953) and Garland and Cook (1955) between Cambridge, Teddington, and Washington, seem likely to contain an error of this magnitude, it would appear to lie in the Cambridge to New Zealand pendulum connection, which has accordingly been discarded. The value 980 509.5 mgal at *CHRISTCHURCH A*, based on Woollard's connections to Washington, has therefore been adopted as the datum for the New Zealand Potsdam System (1959). This value is 5.04 mgal greater than g_s at this station; hence the values of gravity (g_i) in the New Zealand Potsdam System (1959) may be derived from the revised network values (g_s) by the transformation

$$g_i = g_s + 5.04.$$

RELATION BETWEEN THE NEW ZEALAND POTSDAM SYSTEM (1959) AND THE NEW ZEALAND PROVISIONAL SYSTEM

The relation between the gravity values g_i in the New Zealand Potsdam System (1959) and the values g_1 in the New Zealand Provisional System may be written as:

$$g_i = g_1 + \Delta$$



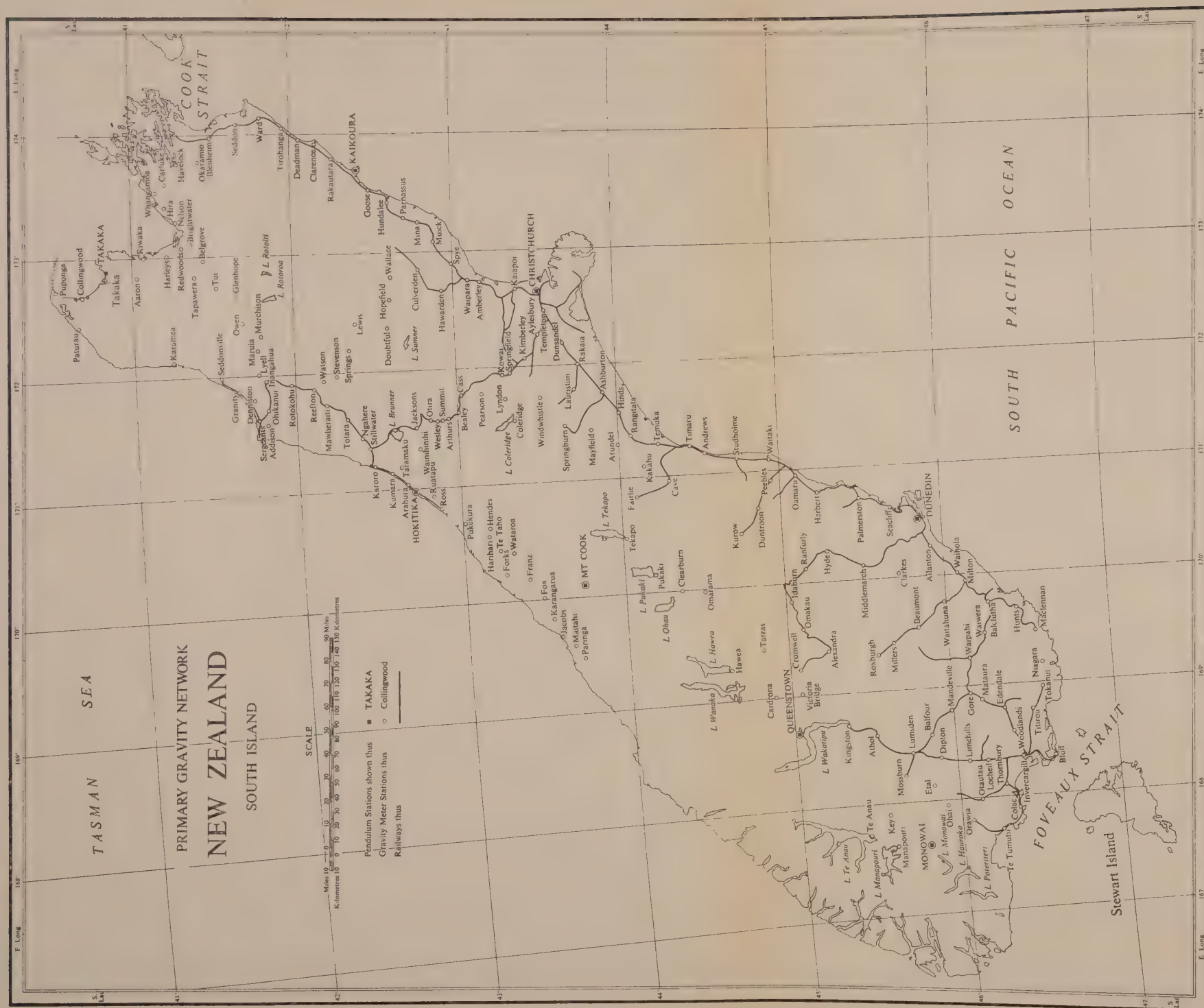


FIG. 2—Location of stations of the Primary Gravity Network in the South Island, New Zealand.



FIG. 3—Circuit diagram for the North Island Network.

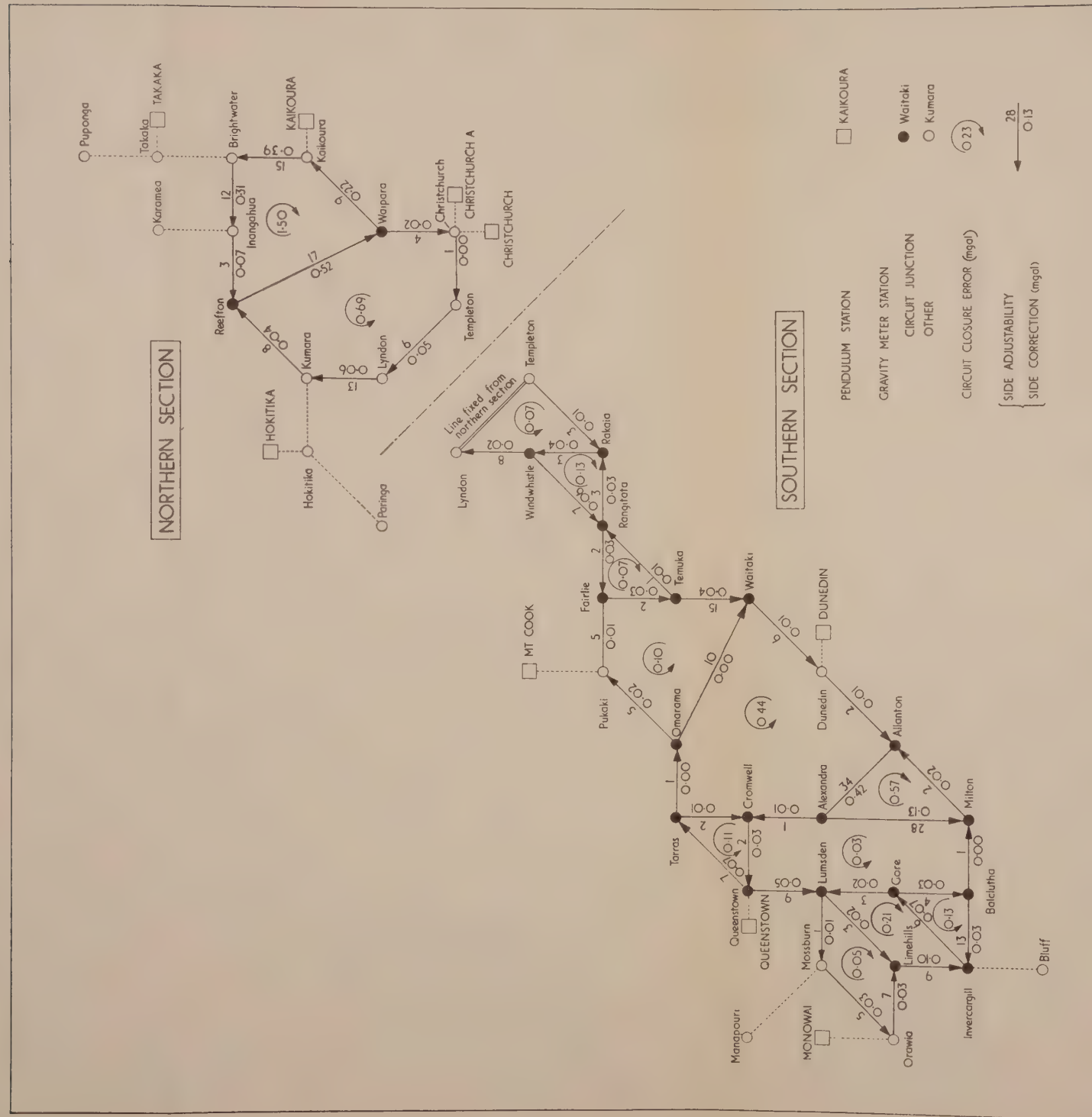


Fig. 4—Circuit diagram for the South Island Network.

where the value of the correction Δ for the North Island is

$$\Delta_n = + 5.24 - 0.00045 (g_1 - 979\ 000)$$

and for the South Island is

$$\Delta_s = + 7.56 - 0.00155 (g_1 - 979\ 000)$$

The value of Δ in the North Island varies from + 4.65 to + 4.90 mgal, and in the South Island from + 4.75 to + 5.55 mgal. Hence anomaly maps already published (see appendix B) in the New Zealand Provisional System would have an error no greater than ± 0.2 mgal if the contour values were corrected by + 4.8 mgal for the North Island, or no greater than ± 0.5 mgal with a correction of + 5.2 mgal for the South Island. For maps covering the whole country, a single correction of + 5.0 mgal would involve an error not greater than ± 0.6 mgal.

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APPENDIX A

VALUES OF GRAVITY AND GRAVITY ANOMALIES IN THE NEW ZEALAND POTSDAM SYSTEM (1959) AT THE STATIONS OF THE PRIMARY GRAVITY NETWORK

The accompanying tables list the values of gravity and gravity anomalies in the New Zealand Potsdam System (1959) at the stations of the Primary Gravity Network. The free air anomaly is the difference between the observed value of gravity at a station and the theoretical value, derived from the International Gravity Formula (1930) on the assumption that there is no mass external to the geoid, or sea level surface. The Bouguer anomaly is further derived from the free air anomaly by removing the attraction of the mass above the geoid in the vicinity of the station. No anomaly maps are given here; the authors have already published a map of Bouguer anomalies (Robertson and Reilly, 1958) in the New Zealand Provisional System, based not only on the 437 network stations but also upon many thousands of additional observations throughout New Zealand.

The quantities in the tables were obtained as follows:

- (a) *Height*: The heights of most stations above mean sea level were obtained from railway levels and other existing survey information, except those marked by an asterisk (*), which were obtained by barometric levelling.
- (b) *Observed Gravity*: The values of observed gravity in the New Zealand Potsdam System (1959) are given to 0.01 mgal; the second digit after the decimal should be used only to derive gravity differences between stations.
- (c) *Free Air Anomaly*: The free air anomaly was derived from the value of the observed gravity, by applying the simple form of the free

air reduction ($+ 0.3086$ mgal per metre), and then by subtracting the value of normal gravity at sea level according to the International Gravity Formula (1930) (Jung 1956; Garland 1956).

- (d) *Bouguer Anomalies*: The Bouguer anomalies were derived from the free air anomaly by applying the Bouguer reduction $- 0.04185 \sigma$ mgal per metre, where σ is the density of the rock lying between the station and sea level; and by adding a terrain correction (Hammer, 1949) based on the preferred density and extending out to Hammer's zone M (21.9 km; approximately equivalent to Hayford's zone K).

The Bouguer anomalies in column (1) were derived using a single conventional value $\sigma = 2.67/\text{cm}^3$. The Bouguer anomalies in column (2) were derived using the actual densities of the rock lying below the station which are shown in the last column.

PRIMARY GRAVITY NETWORK			NEW ZEALAND - NORTH ISLAND			N.Z. POTSDAM SYSTEM (1959)			
Station	Latitude South	Longitude East	Height m	Observed Gravity mgal	Terr. Corr. mgal	Free Air mgal	Bouguer (1) mgal	Bouguer (2) mgal	Rock Density g/cm ³
No. Name	°	°							
1 Alton	39 40.0	174 26.8	130	980 081.3 ₀	0.1	- 30	- 44	- 41	2.15
2 Aranga	35 44.8	173 37.4	149	979 805.3 ₀	0.4	+ 42	+ 26	+ 26	2.62
3 Ardeen	38 55.9	177 16.5	63	979 989.7 ₀	0.3	- 77	- 83	- 82	2.15
4 Ashurst	40 18.9	175 40.0	76	980 099.4 ₁	0.2	- 86	- 94	- 92	2.15
5 Atiamuri	38 23.8	176 01.6	276	979 981.4 ₀	0.4	+ 28	- 3	+ 3	2.15
6 Ava	41 13.3	174 53.5	3	980 284.1 ₈	0.7	- 4	- 4	- 4	2.15
7 Awakaponga	37 55.9	176 45.5	7	980 027.0 ₁	0.1	+ 31	+ 30	+ 31	2.15
8 Awakeri	37 59.9	176 53.0	9	980 043.6 ₀	0.2	+ 42	+ 42	+ 42	2.15
9 Awakino	38 40.1	174 38.7	8*	980 103.6 ₇	0.5	+ 43	+ 43	+ 43	2.15
10 Awarua	35 34.7	173 50.1	88	979 830.1 ₄	0.5	+ 63	+ 53	+ 55	2.3
11 Bay View	39 25.3	176 52.5	5	980 033.7 ₄	0.1	- 94	- 94	- 94	2.15
12 Bombay	37 11.5	174 59.1	171	979 948.6 ₄	0.2	+ 68	+ 49	+ 50	2.5
13 Bridge Pa	39 39.3	176 46.0	20	980 089.3 ₉	0.1	- 54	- 57	- 56	2.15
14 Carterton	41 02.1	175 31.0	72	980 270.6 ₈	0.4	+ 20	+ 13	+ 14	2.15
15 Crownthorpe	39 30.8	176 33.2	299	979 969.7 ₈	0.5	- 75	- 108	- 102	2.15
16 Dairy Flat	36 40.4	174 38.3	64	979 935.0 ₈	0.1	+ 66	+ 59	+ 60	2.3
17 Damestrake	40 13.5	176 04.9	198	980 106.9 ₄	0.1	- 32	- 54	- 50	2.15
18 Eketahuna	40 39.0	175 42.4	232	980 177.4 ₂	1.0	+ 11	- 14	- 9	2.15
19 Eltham	39 25.3	174 18.1	226	980 058.1 ₈	0.2	- 2	- 27	- 22	2.15
20 Erenbun	39 32.6	175 53.4	658*	979 937.5 ₈	1.1	+ 1	- 72	- 60	2.24
21 Erua	39 13.8	175 23.9	743	979 957.3 ₆	0.4	+ 75	- 8	+ 2	2.34
22 Featherston	41 07.1	175 21.5	41	980 280.6 ₈	0.6	+ 13	+ 9	+ 10	2.15
23 Feilding	40 14.7	175 35.1	67	980 061.2 ₈	0.0	- 120	- 128	- 126	2.15
24 Fordell	39 57.7	175 11.8	140	979 998.7 ₁	0.1	- 135	- 151	- 148	2.15
25 Frasertown	38 58.0	177 24.4	22	980 016.4 ₉	0.5	- 66	- 68	- 67	2.15

26	Gisborne	..	..	38	37.2	177	56.2	7	980 022.4 ₈	0.1	34	34	2.15
27	Glenross	..	..	39	27.0	176	29.4	340	979 966.6 ₇	0.6	90	90	2.15
28	Glott	..	..	36	27.2	174	26.1	9	979 916.3 ₄	0.5	49	49	2.15
29	Halconbe	..	..	40	08.8	175	29.6	119	980 026.0 ₆	0.1	142	142	2.15
30	Halls Bridge	..	..	38	52.5	177	13.0	91	979 976.0 ₇	0.5	85	85	2.15
31	Hatpe	..	..	38	51.4	176	01.3	361	979 993.7 ₈	0.4	6	6	2.15
32	Heao	..	..	38	58.4	174	58.6	158	980 075.3 ₀	0.3	20	20	2.15
33	Helena Bay	..	..	35	26.2	174	21.4	8	979 838.3 ₀	0.8	58	58	2.15
34	Henderson	..	..	36	51.8	174	37.8	25	979 941.1 ₃	0.0	41	41	2.15
35	Hicks Bay	..	..	37	35.6	178	17.5	8*	979 938.0 ₉	0.3	29	29	2.15
36	Hibitahi	..	..	39	34.2	175	42.4	742	979 923.2 ₁	1.3	56	56	2.15
37	Hobsonville	..	..	36	48.1	174	38.6	32	979 942.4 ₆	0.0	50	50	2.15
38	Huroa	..	..	39	15.1	174	29.1	190	980 078.8 ₈	0.1	7	7	2.15
39	Hunterville	..	..	39	56.1	175	34.4	268	979 987.4 ₈	0.3	128	128	2.15
40	Huntly	..	..	37	33.4	175	09.6	14	980 021.8 ₇	0.1	60	60	2.15
41	Inglewood	..	..	39	09.6	174	12.5	201	980 066.4 ₄	0.3	4	4	2.15
42	Karo	..	..	35	04.8	173	45.5	3	979 809.1 ₈	0.6	58	58	2.15
43	Kai Iwi	..	..	39	48.3	174	52.1	203	980 035.2 ₀	0.3	83	83	2.15
44	Kangaroo	..	..	38	26.4	176	32.4	546	979 948.1 ₈	0.1	17	17	2.5
45	Kaitia	..	..	35	05.5	173	15.4	11	979 812.7 ₇	0.1	62	62	2.15
46	Katoteke	..	..	41	04.8	175	11.5	219	980 235.0 ₈	1.1	3	3	2.62
47	Kawaka	..	..	36	09.9	174	26.6	26	979 884.6 ₉	0.1	45	45	2.3
48	Karioi	..	..	39	26.9	175	30.7	631	979 958.6 ₀	0.7	34	34	2.15
49	Katikati	..	..	37	32.2	175	54.8	9	980 000.5 ₃	0.6	40	40	2.15
50	Kaukapakapa	..	..	36	37.0	174	29.6	6	979 924.7 ₁	0.2	42	42	2.15
51	Kauri	..	..	35	38.6	174	18.0	136	979 825.5 ₂	0.2	52	52	2.62
52	Kawakawa	..	..	35	22.9	174	03.9	8	979 837.6 ₀	0.4	62	62	2.15
53	Kawera	..	..	39	33.3	176	42.2	43	980 043.9 ₃	0.2	88	88	2.15
54	Kerepehi	..	..	37	18.8	175	33.9	5	979 985.9 ₁	0.1	43	43	2.15
55	Kerikeri	..	..	35	12.4	173	55.1	87	979 808.2 ₃	0.1	63	63	2.62
56	Kirikopuni	..	..	35	51.9	174	01.2	8	979 862.8 ₄	0.2	46	46	2.15

PRIMARY GRAVITY NETWORK			NEW ZEALAND - NORTH ISLAND			N.Z. POTSDAM SYSTEM (1959)			
Station	Latitude South	Longitude East	Height	Observed Gravity	Terr. Corr.	Free Air	Bouguer (1)	Bouguer (2)	Rock Density
No. Name	° ' "	° ' "	m	mgal	mgal	mgal	mgal	mgal	g/cm ³
57 Kokako	..	38 49.2	177 08.0	979 919.5 ₆	1.6	- 41	- 81	- 73	2.15
58 Kopaki	..	38 28.7	175 16.4	980 038.6 ₂	0.2	+ 75	+ 45	+ 51	2.15
59 Koutu	..	35 29.3	173 25.7	979 813.5 ₂	1.4	+ 28	+ 29	+ 29	2.3
60 Lake Houie	..	38 45.4	177 09.3	979 865.9 ₄	2	- 6	- 76	- 69	2.4
61 Lake Obia	..	34 59.6	173 21.9	979 802.8 ₆	0.1	+ 60	+ 59	+ 60	2.3
62 Levin	..	40 34.9	175 16.8	980 140.6 ₇	0.3	- 86	- 88	- 88	2.15
63 Longburn	..	40 22.3	175 32.3	980 100.0 ₈	0.1	- 108	- 109	- 109	2.15
64 Makera	..	40 29.7	175 26.6	980 138.2 ₈	0.2	- 85	- 85	- 85	2.15
65 Mamaranui	..	35 50.1	173 45.2	979 836.2 ₉	0.4	+ 24	+ 23	+ 23	2.15
66 Manaia	..	39 33.0	174 06.0	980 092.6 ₉	0.1	- 28	- 35	- 33	2.15
67 Mangamuka	..	35 12.7	173 32.3	979 815.5 ₈	0.6	+ 59	+ 57	+ 58	2.15
68 Mangamuku	..	38 17.6	177 23.1	979 946.4 ₈	4	- 21	40	- 39	2.62
69 Mangatawhiri	..	37 13.0	175 07.4	979 979.0 ₀	0.2	+ 52	+ 49	+ 49	2.15
70 Mangatepoko	..	39 04.4	175 33.7	979 954.7 ₅	1.0	+ 92	+ 8	+ 11	2.58
71 Mangaweka	..	39 49.6	175 46.7	979 989.0 ₀	1.6	- 75	- 110	- 103	2.15
72 Mangonui	..	34 59.7	173 30.1	979 799.5 ₉	0.2	+ 62	+ 59	+ 60	2.15
73 Marahakoa	..	37 40.6	177 48.0	979 961.5 ₈	1.2	- 12	- 12	- 11	2.15
74 Maranui	..	37 52.3	177 36.1	979 989.1 ₆	0.8	0	- 1	1	2.62
75 Marataha	..	38 49.8	177 53.5	980 080.2 ₂	1.0	+ 21	+ 16	+ 17	2.15
76 Maramarua	..	37 15.2	175 14.5	979 988.7 ₅	0.3	+ 64	+ 59	+ 60	2.15
77 Maromaku	..	35 28.9	174 06.0	979 832.4 ₉	0.4	+ 67	+ 59	+ 61	2.15
78 Marton	..	40 05.8	175 21.8	980 012.7 ₂	0.1	- 132	- 148	- 145	2.15
79 Masterton	..	40 53.9	175 38.4	980 230.6 ₂	0.3	+ 16	0	+ 3	2.15
80 Matabiwi	..	39 34.0	175 16.0	980 016.4 ₆	2	- 32	- 64	- 57	2.15
81 Matamata	..	37 48.8	175 46.3	980 007.4 ₁	0.1	+ 39	+ 32	+ 34	2.15
82 Matawai	..	38 21.1	177 32.0	979 881.6 ₈	0.8	+ 11	- 48	- 44	2.5
83 Matiere	..	38 46.2	175 05.4	980 069.2 ₂	0.2	+ 47	+ 29	+ 33	2.15

84	Maungatapere..	..	35	45.9	174	12.3	146	979 837.4 ₃	0.1	+	72	56	2.62
85	Maungaturoto	..	36	47.3	174	19.9	41	979 880.0 ₅	0.2	+	51	48	2.3
86	Mauriceville	..	40	48.6	175	37.2	246	980 205.0 ₀	0.8	+	28	3	2.5
87	Mercer	..	37	18.9	175	04.0	8	979 991.5 ₀	0.1	+	50	50	2.15
88	Mihi	..	38	29.3	176	17.0	292	979 978.4 ₅	0.2	+	22	5	2.15
89	Mohaka	..	39	06.5	177	11.6	24	980 019.9 ₄	0.1	77	74	76	2.15
90	Mohaka River	..	39	10.5	176	37.5	387*	979 943.5 ₃	0.6	87	44	81	2.3
91	Mokau	..	38	42.1	174	37.7	5	980 099.6 ₉	0.6	36	+	36	2.15
92	Morere	..	39	01.0	177	46.1	18	980 114.4 ₄	0.7	27	+	26	2.15
93	Morrinsville	..	37	39.8	175	31.1	27	980 025.3 ₃	0.0	59	+	57	2.15
94	Murivai	..	38	45.4	177	55.3	5	980 072.5 ₄	0.4	4	+	4	2.15
95	Murupara	..	38	27.4	176	41.7	188	980 001.1 ₀	0.2	15	+	2	2.15
96	National Park	..	39	10.7	175	23.6	807	979 951.9 ₇	0.4	93	+	8	2.54
97	Naunai	..	36	06.0	173	58.9	11	979 874.0 ₀	0.0	38	+	37	2.15
98	New Plymouth	..	39	05.5	174	08.8	98	980 087.2 ₁	0.2	17	+	9	2.15
99	Ngaurua	..	37	40.4	175	40.6	34	980 003.9 ₅	0.1	39	+	36	2.15
100	Ngauruhia	..	37	40.3	175	08.9	21	980 014.2 ₈	0.2	45	+	44	2.15
101	Ngauroro	..	39	23.9	176	19.6	485*	979 945.1 ₃	2	32	-	84	2.62
102	Ngawha	..	35	23.7	173	50.3	250	979 772.2 ₇	0.1	70	+	43	2.62
103	Normanby	..	39	33.0	174	16.5	109	980 074.9 ₇	0.1	32	-	42	2.15
104	Oakura	..	39	06.2	173	58.3	45	980 101.6 ₁	0.6	15	+	11	2.15
105	Oeo	..	39	32.4	173	58.8	47	980 102.8 ₆	0.1	22	-	26	2.15
106	Ohakea	..	39	24.3	175	25.3	619	979 970.3 ₄	1.0	34	+	21	2.15
107	Ohau	..	40	40.7	175	13.0	18	980 172.3 ₃	0.5	63	-	64	2.15
108	Ohinepaka	..	39	01.0	177	20.2	20	980 023.3 ₀	0.1	64	-	66	2.15
109	Ohinepanea	..	37	49.3	176	33.8	8	980 051.8 ₈	0.1	66	+	65	2.15
110	Ohinewai	..	37	29.5	175	09.4	9	980 009.8 ₀	0.0	53	+	52	2.15
111	Ohirangi	..	36	42.1	174	26.4	4	979 921.6 ₅	0.1	32	+	32	2.15
112	Ohura	..	38	50.9	174	58.7	151	980 074.3 ₃	0.3	43	+	29	2.15
113	Oio	..	39	03.2	175	22.6	521	980 015.6 ₄	0.8	80	+	23	2.62

PRIMARY GRAVITY NETWORK			NEW ZEALAND - NORTH ISLAND			N.Z. POTSDAM SYSTEM (1959)					
No.	Name	Station	Latitude South	Longitude East	Height	Observed Gravity	Terr. Corr.	Free Air	Bouguer (1)	Bouguer (2)	Rock Density
			°	'	m	mgal	mgal	mgal	mgal	mgal	g/cm ³
114	Okakukura	..	38 47.9	175 13.4	179	980 068.7 ₉	0.3	+ 50	+ 30	+ 34	2.15
115	Okorire	..	37 58.7	175 50.1	107	980 012.2 ₄	0.2	+ 43	+ 31	+ 34	2.15
116	Omokoroa	..	37 41.0	176 01.4	43	980 011.8 ₁	0.5	+ 49	+ 44	+ 45	2.15
117	Ongarue	..	38 43.1	175 16.9	193	980 057.1 ₈	0.2	+ 50	+ 28	+ 33	2.15
118	Opepe	..	38 46.9	176 13.9	729	979 937.9 ₉	0.3	+ 90	+ 9	+ 12	2.57
119	Opotiki	..	38 00.4	177 17.1	10	980 008.8 ₂	0.3	+ 7	+ 6	+ 7	2.15
120	Opourua	..	39 46.7	175 18.9	122	980 023.2 ₉	1.1	-100	-112	-110	2.15
121	Opunake	..	39 24.7	173 49.4	35	980 108.8 ₉	0.2	- 9	- 12	- 12	2.15
122	Orewa	..	36 35.0	174 41.6	3	979 924.5 ₉	0.1	+ 45	+ 44	+ 44	2.15
123	Otamao	..	39 47.3	175 15.5	105	980 026.6 ₀	1.0	-103	-113	-111	2.15
124	Otaramarae	..	38 00.5	176 22.0	314	979 980.4 ₇	0.4	+ 73	+ 38	+ 45	2.15
125	Otoko	..	38 27.8	177 38.8	196	979 941.6 ₄	0.4	- 43	- 64	- 60	2.15
126	Otorohanga	..	38 11.4	175 12.7	37	980 065.8 ₈	0.1	+ 57	+ 53	+ 54	2.15
127	Oweka	..	37 35.8	178 09.1	58*	979 922.5 ₃	0.8	- 28	- 34	- 33	2.15
128	Paengaroa	..	37 51.9	176 23.3	96	980 005.3 ₁	0.1	+ 43	+ 32	+ 34	2.15
129	Paeroa	..	37 23.5	175 39.8	12	979 993.4 ₁	0.3	+ 46	+ 45	+ 45	2.15
130	Pahiataua	..	40 28.6	175 49.1	128	980 146.7 ₆	0.3	- 37	- 51	- 48	2.15
131	Pakaraka	..	35 21.3	173 57.5	82	979 824.2 ₅	0.1	+ 74	+ 65	+ 65	2.62
132	Pakeia	..	35 41.2	173 53.6	69	979 828.9 ₀	0.8	+ 46	+ 39	+ 41	2.15
133	Papakauri	..	38 34.7	174 50.7	58*	980 084.9 ₄	0.2	+ 48	+ 42	+ 43	2.15
134	Papakura	..	37 04.9	174 56.6	26	979 964.8 ₀	0.1	+ 49	+ 46	+ 47	2.15
135	Papatoetoe	..	36 59.2	174 52.2	23	979 962.3 ₆	0.0	+ 54	+ 51	+ 52	2.15
136	Parakino	..	39 50.9	175 07.7	20	980 048.4 ₀	1.1	-112	-113	-113	2.15
137	Paraparaumu	..	40 54.5	175 00.6	5	980 215.7 ₈	0.6	- 44	- 44	- 44	2.15
138	Pilbrow	..	36 02.1	174 24.9	27	979 887.3 ₁	0.3	+ 62	+ 59	+ 60	2.15
139	Piopia	..	38 28.1	175 01.0	137*	980 059.3 ₆	0.2	+ 57	+ 42	+ 45	2.15
140	Piraka	..	38 55.5	175 20.3	230	980 070.0 ₉	0.3	+ 56	+ 30	+ 31	2.62
141	Piripana	..	38 50.6	177 09.9	136	979 966.6 ₅	0.9	- 69	- 84	- 81	2.15
142	Pokaka	..	39 17.7	175 23.3	812	979 942.4 ₀	0.4	+ 75	+ 15	- 5	2.37

143	Pokeno	..	..	37	14.9	175	01.1	25	979 979.2 ₀	0.2	+	48	46	2.15
144	Porirua	..	..	41	07.9	174	50.3	2	980 260.8 ₀	0.8	-	20	19	2.15
145	Portland	..	..	35	47.8	174	43.1	15	979 862.7 ₁	0.4	+	55	54	2.15
146	Poukawa	..	..	39	45.2	176	43.1	33	980 112.4 ₄	0.1	+	36	39	2.15
147	Punaho	..	..	39	12.0	173	49.7	48	980 102.3 ₈	0.3	+	7	4	2.15
148	Putaruru	..	..	38	03.2	175	46.9	162	980 013.9 ₈	0.1	+	55	41	2.15
149	Putorino	..	..	39	08.5	176	59.1	109	979 980.7 ₆	0.2	-	90	100	2.15
150	Raetihi	..	..	39	26.0	175	17.2	518	979 988.8 ₈	0.2	+	18	28	2.15
151	Rahotu	..	..	39	19.8	173	48.2	50	980 104.6 ₁	0.3	+	1	5	2.15
152	Rangabua	..	..	35	18.5	173	39.1	12	979 824.3 ₉	0.6	+	57	56	2.3
153	Rangipo	..	..	39	04.1	175	49.1	518*	979 984.6 ₈	0.7	+	47	1	2.22
154	Rangitiki	..	..	38	52.9	176	22.3	702	979 921.7 ₈	0.2	+	57	18	2.57
155	Rangitikei	..	..	39	29.5	176	02.1	575*	979 956.6 ₆	1.8	-	1	63	2.62
156	Rotorua	..	..	38	26.2	176	20.3	295	979 976.5 ₁	0.1	+	25	1	2.15
157	Risington	..	..	39	20.6	176	44.8	223*	979 968.2 ₈	0.7	-	85	105	2.15
158	Riverhead	..	..	36	45.3	174	36.8	26	979 939.5 ₈	0.1	+	52	50	2.15
159	Rotorua	..	..	38	08.7	176	15.1	286	979 967.8 ₀	0.1	+	40	14	2.15
160	Ruakura	..	..	37	47.1	175	21.1	44	980 021.5 ₉	0.0	+	50	46	2.15
161	Ruatapu	..	..	38	36.6	176	57.1	402	979 940.2 ₇	0.4	+	7	37	2.62
162	Ruatoria	..	..	37	53.7	178	17.6	61*	979 945.4 ₀	0.3	-	31	36	2.15
163	Ruawai	..	..	36	07.4	174	05.8	12	979 876.5 ₉	0.1	+	39	39	2.15
164	Rukuhia	..	..	37	51.9	175	16.9	55	980 026.9 ₆	0.0	+	52	46	2.15
165	Stratford	..	..	39	20.2	174	17.7	303	980 049.6 ₆	0.2	+	22	6	2.15
166	Tabora	..	..	39	02.0	174	48.2	178	980 072.6 ₉	0.3	+	33	13	2.15
167	Taihape	..	..	39	40.7	175	47.8	443	979 975.0 ₈	1.6	-	40	88	2.15
168	Takapau	..	..	40	01.1	176	21.4	232	980 087.1 ₁	0.1	-	23	49	2.15
169	Tararua	..	..	39	02.0	176	34.4	466	979 938.7 ₅	0.8	-	12	64	2.62
170	Tararua	..	..	39	26.2	176	13.5	600*	979 934.6 ₁	2.0	-	10	74	2.62
171	Tarukenga	..	..	38	04.7	176	09.2	393	979 943.4 ₈	0.2	+	54	19	2.15
172	Taurarunui	..	..	38	52.8	175	15.9	172	980 078.7 ₃	0.2	+	50	31	2.31
173	Taupiri	..	..	37	37.1	175	11.2	15	980 021.1 ₀	0.2	+	54	53	2.15
174	Tauranga	..	..	37	43.5	176	11.7	3	980 028.1 ₂	0.4	+	49	49	2.15
175	Tautoro	..	..	35	29.0	173	50.2	114*	979 806.9 ₈	0.2	+	56	45	2.3

PRIMARY GRAVITY NETWORK			NEW ZEALAND - NORTH ISLAND			N.Z. POTSDAM SYSTEM (1959)					
No.	Name	Station	Latitude South	Longitude East	Height m	Observed Gravity mgal	Terr. Corr. mgal	Free Air mgal	Bouguer (1) mgal	Bouguer (2) mgal	Rock Density g/cm ³
176	Te Aroha	..	37 33.5	175 41.5	15	979 999.5 _a	0.5	+ 39	+ 38	+ 38	2.15
177	Te Awamutu	..	38 00.6	175 18.6	51	980 037.3 _a	0.1	+ 48	+ 43	+ 44	2.15
178	Te Horo	..	40 47.2	175 07.3	12	980 189.5 _a	0.5	- 57	- 58	- 58	2.15
179	Te Kaha	..	37 45.2	177 40.9	8	979 976.0 ₄	0.6	- 4	- 4	- 4	2.5
180	Te Karaka	..	38 28.5	177 52.1	40	979 987.0 ₇	0.1	- 46	- 51	- 50	2.15
181	Te Kaunohata	..	37 24.3	175 08.6	13	980 006.1 ₇	0.0	+ 58	+ 57	+ 57	2.15
182	Te Kaiti	..	38 20.3	175 09.9	55	980 077.4 ₇	0.2	+ 61	+ 55	+ 56	2.15
183	Te Puia	..	38 03.2	178 17.7	201*	979 949.3 ₈	0.9	+ 3	- 19	- 16	2.3
184	Te Puke	..	37 47.3	176 20.2	24	980 026.7 ₉	0.3	+ 49	+ 46	+ 47	2.15
185	Te Rapa	..	37 44.7	175 13.6	34	980 002.0 ₈	0.0	+ 31	+ 27	+ 28	2.15
186	Te Wera	..	39 14.5	174 35.0	173	980 083.3 ₈	0.3	+ 23	+ 4	+ 8	2.15
187	Te Whaiti	..	38 34.2	176 46.3	301	979 977.5 ₄	0.6	+ 16	- 17	- 16	2.62
188	Te Wharau	..	35 54.1	173 53.5	5	979 854.1 ₀	0.0	+ 33	+ 33	+ 33	2.15
189	Tikitiki	..	38 04.8	176 19.5	284	979 973.9 ₈	0.1	+ 51	+ 19	+ 25	2.15
190	Tikitiki	..	37 47.3	178 23.2	27*	979 933.2 ₁	0.6	- 44	- 46	- 46	2.15
191	Tiitiki	..	35 44.1	174 04.1	46	979 847.3 _a	0.1	+ 53	+ 48	+ 49	2.15
192	Toko	..	39 20.3	174 23.5	188	980 072.0 _a	0.1	+ 8	- 13	- 9	2.15
193	Tokomaru	..	38 07.7	178 18.9	5*	980 001.2 _a	0.8	- 13	- 12	- 12	2.15
194	Tokoroa	..	38 13.0	175 52.1	334	979 979.4 _a	0.1	+ 60	+ 22	+ 30	2.15
195	Tolaga	..	38 22.6	178 17.8	5*	980 023.3 _a	0.5	- 12	- 12	- 12	2.15
196	Tongaporitua	..	38 49.2	174 35.7	5	980 114.2 _a	0.5	+ 40	+ 40	+ 40	2.15
197	Torere	..	37 57.2	177 29.0	5*	980 004.3 _a	0.5	+ 6	+ 6	+ 6	2.62
198	Trentham	..	41 08.4	175 02.2	52	980 269.5 ₀	1.1	+ 3	- 1	0	2.15
199	Turakina	..	40 03.1	175 11.9	15	980 025.1 ₇	0.1	- 155	- 157	- 156	2.15
200	Turangi	..	38 59.3	175 49.2	377	979 989.6 ₈	0.7	+ 15	- 26	- 18	2.15
201	Tutaematai	..	35 20.0	174 18.0	11	979 835.5 ₇	0.4	+ 65	+ 64	+ 64	2.15
202	Tutira	..	39 12.1	176 52.4	188	979 963.5 ₈	0.1	- 88	- 109	- 105	2.15

203	Urenui	..	..	39	00.2	174	23.0	46	980 094.1 ₁	0.1	+ 16	+ 11	+ 12	2.15
204	Uruti	..	..	..	38	56.6	174	32.0	26	980 111.3 ₉	+ 33	+ 30	+ 31	2.15
205	Victoria Valley	..	..	..	35	09.0	173	24.3	76	979 804.9 ₇	+ 70	+ 62	+ 64	2.3
206	W'aiawa	..	..	..	37	59.2	177	23.5	9*	980 014.0 ₁	+ 14	+ 13	+ 13	2.15
207	W'aibau	..	..	..	37	37.2	177	57.3	5*	979 957.4 ₈	- 12	12	12	2.15
208	W'aihi	..	..	..	37	24.6	175	51.6	107	979 979.5 ₇	+ 60	+ 48	+ 49	2.62
209	W'aima	..	..	..	35	29.5	173	36.4	76	979 810.2 ₁	+ 46	+ 39	+ 40	2.3
210	W'aimamaku	..	..	..	35	33.4	173	26.3	14	979 809.1 ₄	+ 21	+ 20	+ 21	2.15
211	W'aimiba	..	..	..	38	37.0	175	18.7	233	980 036.2 ₈	+ 50	+ 24	+ 29	2.15
212	W'ainui	..	..	..	38	03.7	177	07.9	15*	980 025.5 ₈	+ 21	+ 19	+ 20	2.15
213	W'aoeka	..	..	..	38	10.6	177	17.0	38*	979 997.9 ₈	10	11	11	2.62
214	W'aiotapu	..	..	..	38	20.2	176	23.2	367	979 965.5 ₉	+ 45	+ 5	+ 13	2.15
215	W'aiotukupuna	..	..	..	38	43.5	177	05.0	599	979 879.7 ₇	- 3	68	- 61	2.4
216	W'aiouru	..	..	..	39	28.9	175	40.0	814	979 918.1 ₈	+ 35	56	40	2.21
217	W'aiupapa	..	..	..	39	55.9	176	35.7	141	980 128.2 ₉	3	18	15	2.15
218	W'aiupoua	..	..	..	35	39.3	173	34.2	98	979 811.4 ₉	+ 40	+ 31	+ 32	2.62
219	W'aiapu	..	..	..	35	56.2	174	26.8	47	979 874.2 ₆	+ 64	+ 59	+ 60	2.15
220	W'aiupunga	..	..	..	38	57.0	176	31.5	695	979 909.0 ₈	+ 36	41	40	2.62
221	W'airakei	..	..	..	38	37.5	176	05.5	381	979 972.6 ₈	+ 31	11	3	2.15
222	W'aitahauui	..	..	..	38	47.3	176	04.6	361	979 984.4 ₇	+ 23	- 17	- 10	2.15
223	W'aitakaruru	..	..	..	37	13.4	175	27.3	3	979 965.1 ₂	+ 30	+ 29	+ 29	2.15
224	W'aitara	..	..	..	39	01.0	174	13.2	46	980 096.8 ₄	+ 18	+ 13	+ 14	2.15
225	W'aitotara	..	..	..	39	47.0	174	41.8	76	980 081.5 ₅	- 56	65	- 63	2.15
226	W'anganui	..	..	..	39	52.6	174	59.8	137	980 029.6 ₉	- 98	113	- 110	2.15
227	W'arkworth	..	..	..	36	24.9	174	39.4	55	979 901.6 ₈	+ 52	+ 46	+ 47	2.15
228	W'averley	..	..	..	39	46.3	174	35.8	80	980 090.1 ₈	- 45	- 54	- 52	2.15
229	W'ellsford	..	..	..	36	17.7	174	31.5	66	979 892.7 ₉	+ 57	+ 50	+ 51	2.3
230	W'hakakei	..	..	..	39	02.5	177	35.5	5	980 077.6 ₇	- 17	- 17	- 17	2.15

PRIMARY GRAVITY NETWORK			NEW ZEALAND - NORTH ISLAND			N.Z. POTSDAM SYSTEM (1959)					
No.	Name	Station	Latitude South	Longitude East	Height m	Observed Gravity mgal	Terr. Corr. mgal	Free Air mgal	Bouguer (1) mgal	Bouguer (2) mgal	Rock Density g/cm ³
231	W'hakapara ..		35 32.6	174 16.6	94	979 828.3 ₁	0.2	+ 66	+ 55	+ 57	2.3
232	W'hangamomona		39 08.7	174 44.3	156	980 078.6 ₀	0.6	+ 22	+ 5	+ 9	2.15
233	W'hangara ..		38 33.0	178 12.8	11*	980 052.8 ₇	0.2	+ 4	+ 3	+ 3	2.15
234	W'oodville ..		40 21.3	175 51.8	72	980 132.2 ₆	0.6	- 58	- 65	- 63	2.15
P1	AUCKLAND		36 51.8	174 46.7	79	979 948.5 ₉	0.1	+ 68	+ 59	+ 60	2.4
P2	DOUBTLESS BAY		34 59.5	173 29.1	7	979 801.0 ₄	0.3	+ 58	+ 58	+ 58	2.15
P3	HASTINGS		39 39.2	176 46.0	20	980 088.8 ₁		See 13 Bridge Pa			
P4	LOWER HUTT		41 14.2	174 55.0	3	980 294.1 ₅		See 6 Ava			
P5	OPOTIKI		38 00.4	177 17.1	10	980 008.8 ₃		See 119 Opotiki			
P6	ROTORUA		38 08.3	176 15.5	286	979 967.9 ₈		See 159 Rotorua			
P7	RUSSELL		35 15.9	174 07.3	5*	979 824.9 ₂	0.5	+ 58	+ 58	+ 58	2.15
P8	TE ARAROA		37 38.1	178 22.3	5*	979 912.7 ₄	0.5	- 58	- 58	- 58	2.15
P9	WELLINGTON		41 17.2	174 46.1	122	980 266.0 ₇		See 232 W'hangamomona			
P10	W'HANGAMOMONA		39 08.8	174 44.2	156	980 078.7 ₈					

PRIMARY GRAVITY NETWORK				NEW ZEALAND - SOUTH ISLAND				N.Z. POTSDAM SYSTEM (1959)			
No.	Name	Station	Latitude South	Longitude East	Height	Observed Gravity	Terr. Corr.	Free Air	Bouguer (1)	Bouguer (2)	Rock Density
			°	°	m	mgal	mgal	mgal	mgal	mgal	g/cm ³
235	Aaron	..	41 02.1	172 49.3	116*	980 252.8 ₆	4.6	+ 16	+ 7	+ 9	2.25
236	Addison	..	41 48.4	171 35.4	43*	980 333.2 ₇	0.9	+ 5	+ 1	+ 1	2.25
237	Alexandra	..	45 15.0	169 23.9	149	980 584.3 ₇	1.7	- 22	- 37	- 37	2.67
238	Allanton	..	45 54.8	170 15.8	5	980 744.5 ₇	0.5	+ 34	+ 34	+ 34	2.25
239	Amberley	..	43 09.3	172 43.4	46*	980 446.6 ₁	0.1	- 2	- 7	- 7	2.25
240	Andrens	..	44 32.0	171 11.4	18	980 587.9 ₇	0	+ 6	+ 4	+ 5	2.25
241	Arabura	..	42 40.3	171 01.8	7	980 409.4 ₆	0.1	- 8	- 9	- 8	2.25
242	Arburs	..	42 56.7	171 33.9	737	980 243.0 ₆	15.4	+ 26	- 41	- 41	2.67
243	Arundel	..	43 58.8	171 16.8	203	980 470.4 ₈	0.3	- 4	- 27	- 23	2.25
244	Ashburton	..	43 54.1	171 45.2	100	980 507.3 ₉	0	+ 8	- 3	- 1	2.25
245	Athol	..	45 30.8	168 34.8	275	980 596.6 ₆	1.4	+ 6	- 24	- 24	2.67
246	Aylesbury	..	43 31.8	172 15.9	124	980 475.4 ₇	0	+ 17	+ 3	+ 5	2.25
247	Balcutha	..	46 14.7	169 44.3	7	980 798.9 ₈	0.1	+ 60	+ 59	+ 59	2.25
248	Balfour	..	45 50.4	168 35.2	165	980 676.5 ₂	0.1	+ 22	+ 4	+ 4	2.67
249	Bealey	..	43 01.4	171 36.5	619*	980 276.7 ₆	11.0	+ 17	- 42	- 42	2.67
250	Beaumont	..	45 49.4	169 31.7	48	980 703.9 ₆	2.4	+ 15	+ 12	+ 12	2.67
251	Belgrave	..	41 27.0	172 57.5	134	980 277.9 ₈	1.0	+ 9	- 5	- 2	2.25
252	Blenheim	..	41 30.7	173 57.5	5	980 261.7 ₈	0.2	- 52	- 52	- 52	2.25
253	Bluff	..	46 36.0	168 20.6	3	980 868.6 ₆	0.2	+ 97	+ 97	+ 97	2.67
254	Brightwater	..	41 22.6	173 06.5	28	980 281.0 ₁	0.9	- 14	- 16	- 15	2.25
255	Cardrona	..	44 52.9	169 00.2	547*	980 425.2 ₀	2.4	- 25	- 83	- 83	2.67
256	Carlisle	..	41 12.9	173 35.5	46	980 273.6 ₈	1.9	- 1	- 4	- 4	2.67
257	Carruth	..	43 02.3	171 45.2	568	980 291.0 ₇	4.8	+ 14	- 45	- 45	2.67
258	Cave	..	44 18.6	170 57.2	156	980 518.8 ₃	0.5	+ 0	- 17	- 17	2.67
259	Christchurch	..	43 31.8	172 37.2	7	980 509.3 ₇	0	+ 15	+ 14	+ 14	2.25

PRIMARY GRAVITY NETWORK				NEW ZEALAND - SOUTH ISLAND				N.Z. POTSDAM SYSTEM (1959)			
No.	Name	Station	Latitude South	Longitude East	Height	Observed Gravity	Terr. Corr.	Free Air	Bouguer (1)	Bouguer (2)	Rock Density
			°	'	m	mgal	mgal	mgal	mgal	mgal	g/cm ³
260	Clarence	..	42 09.4	173 55.5	10	980 346.9 ₄	1.2	-23	-23	-23	2.25
261	Clarks	..	45 43.7	170 02.8	532*	980 611.2 ₈	0.3	+80	+21	+21	2.67
262	Clearburn	..	44 21.3	170 00.5	500*	980 396.3 ₈	0.7	-21	-76	-76	2.67
263	Colac	..	46 21.8	167 52.6	11*	980 832.4 ₁	0.1	+83	+82	+82	2.25
264	Coleridge	..	43 21.8	171 31.7	362	980 374.6 ₀	5.2	+5	-31	-31	2.67
265	Collingwood	..	40 40.7	172 40.9	6*	980 290.5 ₈	0.5	+52	+51	+51	2.25
266	Cromwell	..	45 03.5	169 12.8	192	980 531.5 ₇	3.0	-44	-62	-62	2.67
267	Culverden	..	42 46.6	172 50.6	175	980 358.0 ₇	0.1	-17	-36	-33	2.25
268	Deadman	..	42 03.2	173 57.4	5*	980 326.0 ₈	2.2	-36	-35	-35	2.25
269	Denniston	..	41 44.3	171 47.8	584*	980 228.3 ₈	6.6	+73	+14	+14	2.67
270	Dipton	..	45 54.0	168 22.1	130	980 689.0 ₁	0.4	+18	+4	+4	2.67
271	Donbifful	..	42 34.1	172 21.5	521	980 253.4 ₄	12.0	+4	-42	-42	2.67
272	Dunedin	..	45 52.0	170 30.9	12*	980 742.4 ₈	0.9	+39	+38	+38	2.75
273	Dunsandel	..	43 39.8	172 11.6	75	980 500.1 ₄	0	+14	+6	+7	2.25
274	Dunroon	..	44 51.4	170 41.1	137	980 592.8 ₇	0.6	+19	+4	+7	2.25
275	Edendale	..	46 18.9	168 47.0	41	980 747.7 ₈	0	+12	+8	+9	2.25
276	Etah	..	45 51.5	168 07.7	206*	980 675.4 ₈	0.5	+32	+10	+13	2.25
277	Fairlie	..	44 06.2	170 49.8	304	980 447.3 ₆	0.7	-7	-40	-40	2.67
278	Forks	..	43 15.1	170 13.9	27*	980 434.5 ₀	1.0	-29	-31	-30	2.25
279	Fox	..	43 28.0	170 01.0	151*	980 424.6 ₃	11.7	-20	-25	-25	2.67
280	Frang	..	43 23.6	170 11.0	137*	980 415.2 ₄	13.5	-27	-29	-29	2.67
281	Glenhope	..	41 38.9	172 39.0	388	980 216.1 ₀	4.5	+8	-31	-30	2.60
282	Goose	..	42 28.8	173 31.7	3*	980 379.2 ₈	5.0	-22	-17	-17	2.67
283	Gore	..	46 06.3	168 56.6	71	980 719.3 ₇	0.3	+12	+5	+6	2.25
284	Granity	..	41 37.8	171 51.3	6	980 324.7 ₁	6.5	+1	+6	+7	2.25

285	Hanibari	..	..	..	43	09.0	170	33.0	40*	980 416.7 ₈	6.4	34	— 32	— 31	2.25
286	Harleys	..	..	..	..	41 12.8	173	00.5	32*	980 281.0 ₁	0.3	2	1	1	2.25
287	Hanelock	..	..	..	..	41 17.3	173	46.1	18*	980 274.9 ₃	4.4	15	13	13	2.67
288	Hanariden	..	..	..	..	42 55.6	172	39.0	243	980 370.3 ₂	0.2	3	24	20	2.25
289	Havea	..	..	..	..	44 37.0	169	15.0	329	980 438.9 ₄	3.5	54	88	88	2.67
290	Hendes	..	..	..	..	43 09.7	170	37.5	85*	980 409.2 ₅	11.9	28	26	26	2.67
291	Herbert	..	..	..	..	45 13.2	170	46.8	83	980 665.5 ₀	0.6	42	33	35	2.25
292	Hinds	..	..	..	..	44 00.3	171	34.2	85	980 505.3 ₆	0	8	17	16	2.25
293	Hira	..	..	..	..	41 12.7	173	23.6	37*	980 284.1 ₇	2.3	7	5	5	2.75
294	Hokitika	..	..	..	..	42 43.2	170	57.7	2*	980 412.5 ₁	0	11	11	11	2.25
295	Ilopesfield	..	..	..	..	42 35.4	172	35.5	393	980 284.8 ₁	7.9	6	42	42	2.67
296	Hundalee	..	..	..	..	42 35.9	173	25.3	34	980 388.2 ₃	2.2	14	16	15	2.25
297	Hunts	..	..	..	..	46 25.5	169	40.3	48	980 783.3 ₈	0.6	40	35	35	2.67
298	Hyde	..	..	..	..	45 18.2	170	15.4	332	980 588.4 ₁	1.6	34	1	5	2.25
299	Idaburn	..	..	..	..	45 02.3	169	49.8	436	980 505.1 ₃	0.5	7	— 41	— 34	2.25
300	Inangahua	..	..	..	..	41 51.3	171	57.1	57	980 333.2 ₆	2.1	5	0	1	2.25
301	Invercargill	..	..	..	..	46 24.8	168	20.7	3	980 827.8 ₂	0	72	71	71	2.25
302	Jacksons	..	..	..	..	42 44.7	171	31.4	183	980 355.0 ₄	9.0	14	26	26	2.67
303	Jacobs	..	..	..	..	43 34.5	169	40.7	3*	980 476.3 ₁	2.4	24	— 22	— 21	2.25
304	Kaitapoi	..	..	..	..	43 23.2	172	39.3	5*	980 480.4 ₀	0	2	3	3	2.25
305	Kaikoura	..	..	..	..	42 24.4	173	40.9	6*	980 378.8 ₈	1.1	15	15	14	2.25
306	Kakahu	..	..	..	..	44 07.8	171	05.2	166	980 504.9 ₉	1.3	5	12	12	2.67
307	Karama	..	..	..	..	41 15.2	172	06.7	2*	980 283.3 ₀	1.6	8	— 7	— 7	2.25
308	Karungatua	..	..	..	..	43 32.2	169	50.2	26*	980 457.4 ₄		32			
309	Karoro	..	..	..	..	42 27.8	171	11.6	9*	980 403.7 ₇	0.2	6	5	5	2.25
310	Key	..	..	..	..	45 32.8	167	53.8	311*	980 605.0 ₆	1.5	22	11	— 5	2.25
311	Kimberley	..	..	..	..	43 26.9	172	04.0	249	980 436.8 ₇	0.1	25	3	1	2.25
312	Kingston	..	..	..	..	45 19.8	168	42.8	313	980 534.2 ₃	4.5	28	— 59	— 59	2.67
313	Kowai	..	..	..	..	43 19.7	171	47.6	562*	980 356.2 ₂	3.8	51	— 8	— 8	2.67
314	Kumara	..	..	..	..	42 35.0	171	07.8	32	980 394.9 ₆	0	7	— 10	— 10	2.25
315	Kurou	..	..	..	..	44 44.2	170	28.2	204	980 544.6 ₆	3.0	2	18	— 18	2.67

PRIMARY GRAVITY NETWORK			NEW ZEALAND - SOUTH ISLAND			N.Z. POTSDAM SYSTEM (1959)					
No.	Name	Station	Latitude	Longitude	Height	Observed Gravity	Terr. Corr.	Free Air	Bouguer		Rock Density
			South	East					(1)	(2)	
316	Lauriston	..	43 44.0	171 46.5	202	980 465.9 ₁	0	+ 13	9	— 6	2.25
317	Lewis	..	42 22.6	172 23.8	866*	980 172.8 ₇	7.8	+ 47	— 42	— 42	2.67
318	Lime Hills	..	46 05.1	168 20.1	66	980 700.7 ₆	0.1	— 6	— 14	— 12	2.25
319	Lochiel	..	46 12.5	168 20.0	38	980 735.6 ₆	0	+ 9	+ 5	+ 5	2.25
320	Lumsden	..	45 44.5	168 26.5	192	980 600.1 ₁	0.4	+ 23	+ 2	+ 2	2.67
321	Lyell	..	41 47.1	172 01.6	84*	980 317.7 ₆	4.9	+ 4	— 1	— 1	2.67
322	Lyndon	..	43 17.7	171 42.6	844	980 283.5 ₆	4.6	+ 69	— 21	— 21	2.67
323	Maclean	..	46 32.5	169 28.7	5	980 794.3 ₁	1.0	+ 27	+ 28	+ 28	2.67
324	Maitahi	..	43 38.4	169 35.2	12*	980 473.2 ₁	4.6	— 30	— 27	— 26	2.25
325	Manapouri	..	45 34.2	167 36.3	185	980 627.1 ₆	1.4	+ 3	— 16	— 13	2.25
326	Mandeville	..	45 59.6	168 48.3	103	980 700.7 ₈	0.3	+ 13	+ 2	+ 4	2.25
327	Mariau	..	41 46.9	172 12.6	140*	980 284.1 ₅	4.7	— 12	— 23	— 23	2.60
328	Mataura	..	46 11.9	168 51.8	52	980 735.3 ₈	0.3	+ 14	+ 8	+ 9	2.25
329	Mawheraiti	..	42 11.5	171 43.2	153	980 320.8 ₆	1.1	— 8	— 24	— 22	2.25
330	Mayfield	..	43 48.9	171 25.0	269	980 447.7 ₃	0.1	+ 8	— 22	— 17	2.25
331	Middlemarch	..	45 30.5	170 07.4	202	980 439.1 ₁	1.2	+ 26	+ 5	+ 5	2.67
332	Millers	..	45 39.9	169 24.8	74	980 668.9 ₂	2.8	+ 2	— 3	— 3	2.67
333	Milton	..	46 07.2	169 57.3	12	980 773.4 ₇	0.2	+ 47	+ 46	+ 46	2.25
334	Mina	..	42 48.7	173 13.6	76	980 407.0 ₆	0.1	— 2	— 10	— 9	2.25
335	Monowai	..	45 47.1	167 36.4	165*	980 652.7 ₈	1.5	+ 3	— 14	— 11	2.25
336	Mosburn	..	45 40.5	168 14.5	293	980 622.7 ₇	0.1	+ 23	— 10	— 5	2.25
337	Mt. Cook	..	43 44.2	170 05.5	748*	980 270.8 ₅	28.0	— 14	— 69	— 69	2.67
338	Muirick	..	42 53.9	173 05.9	72*	980 435.0 ₂	1.2	+ 17	+ 10	+ 10	2.67
339	Murchison	..	41 47.9	172 19.4	158	980 263.1 ₃	1.9	— 29	— 45	— 42	2.25
340	Nelson	..	41 16.4	173 16.5	4	980 278.1 ₆	1.2	— 15	— 14	— 14	2.25
341	Ngahere	..	42 23.8	171 26.1	33	980 372.8 ₉	0.7	— 12	— 15	— 14	2.25
342	Niagara	..	46 34.6	169 08.4	15	980 810.0 ₃	0.9	+ 43	+ 42	+ 42	2.67

343	Oamaru	..	..	45	05.9	170	58.5	9	980 657.5 _g	0.1	+	22	+	21	+	21	2.25
344	Ohai	..	..	45	55.9	167	57.8	210*	980 689.9 ₁	0.4	+	41	+	18	+	22	2.25
345	Ohikamui	..	..	41	50.8	171	42.8	29*	980 347.2 ₁	7.0	+	11	+	15	+	15	2.6
346	Okaramio	..	..	41	25.9	173	45.9	53*	980 274.1 ₄	2.6	+	18	+	21	+	21	2.67
347	Omakau	..	..	45	05.7	169	35.9	304	980 539.8 ₈	0.6	+	4	+	38	+	32	2.25
348	Omarama	..	..	44	29.5	169	58.0	427*	980 434.9 ₇	1.0	+	17	+	64	+	64	2.67
349	Oranvia	..	..	46	03.6	167	47.4	72	980 734.1 ₄	0.2	+	31	+	23	+	25	2.25
350	Otautau	..	..	46	08.8	167	59.8	50	980 767.5 ₆	0.3	+	50	+	45	+	46	2.25
351	Otira	..	..	42	49.9	171	33.8	378	980 307.9 ₈	20.2	+	9	+	31	+	31	2.67
352	Owen	..	..	41	41.4	172	26.1	241*	980 242.7 ₈	5.7	+	14	+	35	+	31	2.25
353	Palmersson	..	..	45	29.2	170	43.0	15	980 713.6 ₇	0.5	+	45	+	44	+	44	2.25
354	Paringa	..	..	43	42.8	169	29.3	27*	980 474.8 ₉	12.7	+	30	+	20	+	20	2.67
355	Parnassus	..	..	42	42.6	173	17.5	32	980 398.7 ₃	0.3	+	14	+	18	+	17	2.25
356	Paitrau	..	..	40	38.8	172	26.0	5*	980 288.3 ₁	0.6	+	52	+	52	+	52	2.25
357	Pearson	..	..	43	08.0	171	46.2	646*	980 290.1 ₇	10.0	+	28	+	34	+	34	2.67
358	Peebles	..	..	44	56.9	170	56.3	68	980 625.3 ₈	0.1	+	22	+	14	+	15	2.45
359	Pukaki	..	..	44	11.3	170	08.0	506	980 375.0 ₂	1.0	+	25	+	81	+	75	2.4
360	Pukekura	..	..	43	00.7	170	40.3	67*	980 397.4 ₇	1.2	+	32	+	38	+	37	2.25
361	Puponga	..	..	40	31.6	172	44.2	3	980 273.6 ₂	0.2	+	47	+	47	+	47	2.45
362	Queenstown	..	..	45	02.1	168	39.4	309	980 506.4 ₅	7.9	+	31	+	57	+	57	2.67
363	Rakaia	..	..	43	45.5	172	01.3	108	980 494.8 ₀	0	+	11	+	1	+	1	2.25
364	Rakautura	..	..	42	16.0	173	48.2	5*	980 360.8 ₆	6.3	+	21	+	15	+	15	2.67
365	Rangitiri	..	..	45	07.8	170	06.1	424	980 525.5 ₉	0.2	+	15	+	32	+	24	2.25
366	Rangitaita	..	..	44	04.0	171	22.4	104	980 507.8 ₄	0	+	5	+	17	+	15	2.25
367	Redwoods	..	..	41	18.1	173	04.5	41*	980 281.9 ₈	0.2	+	2	+	6	+	6	2.25
368	Reefton	..	..	42	06.4	171	51.2	181	980 304.6 ₃	1.2	+	8	+	27	+	24	2.25
369	Rimaka	..	..	41	04.6	172	59.8	3*	980 265.5 ₂	0.7	+	10	+	10	+	10	2.25
370	Ross	..	..	42	53.1	170	48.4	7	980 414.0 ₇	1.3	+	23	+	22	+	22	2.25
371	Rotokohu	..	..	41	58.2	171	53.6	94	980 304.0 ₈	1.4	+	23	+	32	+	31	2.25
372	Roxburgh	..	..	45	33.6	169	19.6	102	980 640.1 ₉	3.1	+	8	+	17	+	17	2.67
373	Ruatapu	..	..	42	49.3	170	54.5	21*	980 405.7 ₈	0.1	+	21	+	23	+	23	2.25

PRIMARY GRAVITY NETWORK			NEW ZEALAND - SOUTH ISLAND			N.Z. POTSDAM SYSTEM (1959)					
No.	Name	Station	Latitude South	Longitude East	Height	Observed Gravity	Terr. Corr.	Free Air	Bouguer (1)	Bouguer (2)	Rock Density
			°	'	m	mgal	mgal	mgal	mgal	mgal	g/cm ³
374	Seacliff	..	45 41.0	170 37.4	98	980 704.8 ₁	1.2	+ 44	+ 34	+ 36	2.25
375	Seddon	..	41 40.4	174 04.4	89	980 254.7 ₁	0.2	- 48	- 58	- 56	2.25
376	Seddonville	..	41 33.0	171 59.0	15	980 327.7 ₄	1.6	+ 13	+ 13	+ 14	2.25
377	Sergeants	..	41 45.6	171 38.8	20	980 333.1 ₂	0.6	+ 2	0	0	2.5
378	Springburn	..	43 40.4	171 28.3	336	980 416.7 ₉	0.8	+ 11	- 26	- 20	2.25
379	Springfield	..	43 20.1	171 55.8	384	980 402.1 ₄	0.7	+ 41	1	+ 6	2.25
380	Springs	..	42 20.1	172 10.9	421	980 267.2 ₁	3.7	+ 8	- 36	- 36	2.67
381	Spye	..	42 59.6	172 53.8	134	980 422.9 ₀	0.4	+ 16	+ 1	+ 3	2.45
382	Stevenson	..	42 16.0	171 58.0	360*	980 278.3 ₁	9.3	+ 6	- 25	- 23	2.6
383	Stillwater	..	42 26.2	171 21.0	27	980 394.8 ₄	1.3	+ 5	+ 3	+ 4	2.25
384	Studholme	..	44 43.7	171 07.7	11	980 607.8 ₃	0.1	+ 6	+ 5	+ 5	2.25
385	Summit	..	42 54.5	171 33.6	922	980 213.7 ₄		+ 57			
386	Takaka	..	40 50.9	172 48.5	5*	980 281.0 ₄	1.3	+ 26	+ 27	+ 27	2.25
387	Tapawera	..	41 23.4	172 49.4	146	980 262.0 ₅	1.2	+ 3	12	- 10	2.25
388	Taramakau	..	42 37.9	171 10.9	81*	980 386.3 ₈	0.2	- 4	- 13	- 12	2.25
389	Tarras	..	44 50.3	169 24.7	270*	980 486.4 ₈	1.0	- 45	- 74	- 74	2.67
390	Te Anau	..	45 25.1	167 42.8	212	980 592.2 ₁	1.3	- 9	- 32	- 28	2.25
391	Tekapo	..	44 00.5	170 28.8	721	980 336.1 ₃	0.8	+ 19	61	61	2.67
392	Templeton	..	43 33.4	172 28.3	40	980 505.2 ₅	0	+ 18	- 14	+ 15	2.25
393	Temuka	..	44 14.7	171 16.8	18	980 550.9 ₃	0	- 5	- 7	- 6	2.25
394	Te Taho	..	43 13.1	170 26.7	44*	980 419.4 ₆	5.4	- 36	- 35	- 34	2.25
395	Te Timutiu	..	46 15.1	167 42.9	56	980 790.9 ₃	0.2	+ 66	- 60	- 61	2.25
396	Thornbury	..	46 17.2	168 06.2	16	980 806.1 ₈	0	+ 66	- 64	- 64	2.25
397	Timaru	..	44 23.9	171 15.3	4	980 573.6 ₀	0.1	0	- 1	- 1	2.75
398	Tirohanga	..	41 57.7	174 03.1	6*	980 314.6 ₀	1.8	- 39	- 38	- 38	2.25
399	Titiroa	..	46 29.5	168 46.1	6	980 803.1 ₀	0.1	- 41	- 40	- 40	2.67
400	Tokanui	..	46 33.8	168 56.7	37	980 809.3 ₀	0.4	- 50	- 46	- 46	2.67

401	Totara	..	..	42	18.2	171	36.8	78	980 356.9 ₈	0.5	5	14	12	2.25
402	Tui	..	..	..	41	32.3	172	43.6	326*	1.3	12	24	18	2.25
403	Victoria Bridge	..	..	..	45	03.0	169	01.7	272	7.1	43	66	66	2.67
404	W'aitohia	..	..	..	46	01.5	170	05.7	3	0.7	36	36	36	2.45
405	W'aituhimahi	..	..	..	42	45.7	171	19.8	91*	8.3	21	23	21	2.25
406	W'aitapahi	..	..	..	46	06.6	169	14.3	105	0.3	49	37	37	2.67
407	W'aitapara	..	..	..	43	03.5	172	45.5	73	0.1	3	11	10	2.25
408	W'aitabuna	..	..	..	45	58.8	169	45.3	101	0.6	38	28	28	2.67
409	W'aitaki	..	..	..	44	56.4	171	05.9	14	0	16	14	14	2.25
410	W'aitera	..	..	..	46	13.0	169	29.5	65	0.3	45	38	38	2.67
411	W'allace	..	..	..	42	35.4	172	46.6	306*	5.3	16	45	45	2.67
412	W'ard	..	..	..	41	49.6	174	09.0	19	0.6	31	33	33	2.25
413	W'ataroa	..	..	..	43	17.7	170	24.7	81*	14.1	42	37	37	2.67
414	W'atson	..	..	..	42	10.4	171	55.7	238*	4.7	8	14	13	2.6
415	W'esley	..	..	..	42	52.8	171	33.4	625*	3.5	7	0	0	2.67
416	W'haingama	..	..	..	41	09.6	173	31.7	40	0.9	1	5	0	2.4
417	W'indwhistle	..	..	..	43	31.0	171	42.8	422	0	41	21	21	2.25
418	W'oodlands	..	..	..	46	21.7	168	33.3	34	0	24	21	21	2.25

See 259 Christchurch

" " "

" 272 Dunedin

" 294 Hokitika

" 305 Kaikoura

" 335 Monowai

" 337 Mt. Cook

" 362 Queenstown

" 386 Takaka

980 509.5₀980 509.7₁980 742.7₀980 412.5₈980 378.6₄980 652.6₁980 270.7₁980 504.3₉980 275.9₉

172 37.2

172 37.2

170 39.0

170 57.7

173 40.9

167 37.3

170 05.5

168 39.4

172 53.1

43 31.8

43 31.8

45 52.0

42 43.2

42 24.4

45 47.1

43 44.2

45 02.0

40 49.9

P11 CHRISTCHURCH A†

P12 CHRISTCHURCH

P13 DUNEDIN

P14 HOKITIKA

P15 KAIKOURA

P16 MONOWAI

P17 MT. COOK

P18 QUEENSTOWN

P19 TAKAKA

† P11 CHRISTCHURCH A is a First Order World Network Station.

APPENDIX B

PUBLISHED WORKS INCORPORATING RESULTS ON THE NEW ZEALAND
PROVISIONAL SYSTEM

Listed below are published works incorporating gravity results in New Zealand. In these the basis for the gravity measurements is variously stated; however, in each case the gravity values are in the New Zealand Provisional System as defined in the present paper, and may be converted to the New Zealand Potsdam System (1959) by the corrections given above.

- DIBBLE, R. R.; SUGGATE, R. P. 1956: Gravity Survey for Possible Oil Structures, Kotuku-Ahaura District, North Westland. *N.Z. J. Sci. Tech. B* 37: 571-86.
- FLEMING, C. A. 1953: The Geology of the Wanganui Subdivision. *N.Z. geol. Surv. Bull. n.s.* 52.
- HATHERTON, T. 1952: Gravity Profiles across the Canterbury Plains. *N.Z. J. Sci. Tech. B.* 34: 13-20.
- MODRINIAK, N.; STUDT, F. E. 1959. The Geological Structure and Volcanism of the Taupo-Tarawera District. *N.Z. J. Geol. Geophys.* 2: 654-84.
- ROBERTSON, E. I.; REILLY, W. I. 1958: Bouguer Anomaly Map of New Zealand. *N.Z. J. Geol. Geophys.* 1: 560-4.
- STUDT, F. E. 1958. Geophysical Reconnaissance at Kawerau, New Zealand. *N.Z. J. Geol. Geophys.* 1: 219-46.

ON THE ABUNDANCE OF MESOSCOPIC FOLDS IN THE ALPINE SCHISTS OF NEW ZEALAND

By A. R. LILLIE, Department of Geology, University of Auckland

(Received for publication, 31 July 1959)

Summary

This note stresses certain aspects of earlier work in the Alpine schists of New Zealand, particularly the abundance of mesoscopic folds and the diversity of relations of schistosity planes to relict stratification planes.

In his stimulating speculations on the tectonic history of New Zealand Dr Kingma (1959) has mentioned work done by two colleagues and myself (Lillie, Gunn, and Robinson 1957) on the structure of schists in the New Zealand Alps.

Beyond acknowledging many interesting facts and ideas learnt from a reading of Dr Kingma's general geotectonic scheme I am not, in this note, concerned in commenting on that scheme; I wish, however, to correct some wrong impressions of our work conveyed by his paper, and to question some of the deductions on pages 35-41 of that paper for whose support he seems to rely partly on a misunderstanding of our own work.

Dr Kingma says, (p. 35) "Simple horizontal lineation, or lineation undulating about the horizontal, has been observed (Wellman *et al.*, 1952; Lillie *et al.*, 1957), due to simple schistosity without crumpling, probably resulting from severe stretching and slip. The schistosity planes are usually vertical and parallel to the bedding planes; beds of at least Triassic age have been affected." As regards the work done by my two colleagues and myself, this statement is quite misleading. It should be made clear that our study was very largely concerned with mesoscopic *folds* (using Weiss's, 1958, more appropriate term for what are generally called microfolds) and we must have seen tens of thousands of these and measured scores of them. We made no statistical plots because we saw very consistent patterns very clearly over extensive rock faces and we wished to cover difficult ground fairly quickly. Each of our symbols for dip and strike of bedding planes and schistosity planes on our map should be taken to represent anything between three to ten *actual measurements*; the scale of the published map was too small to permit the recording of all measurements. Examination of intervening rock walls showing very abundant examples confirmed the general validity of our measurements.

Our sections along the Fox and Franz Josef glaciers are intended to show the patterns of "drag folds" (mesoscopic folds = microfolds), affecting the relict bedding surfaces, and of schistosity planes which have usually an axial-plane relationship to the folds. The maps and sections, which show much detail for certain parts of the field, should make it quite clear that bedding surfaces (S_1) are commonly over-printed by planes of schistosity (S_2) and sometimes by other schistosity surfaces (S_3) and (S_4) and it is evident that these surfaces are often far from coincident, although they gen-

erally intersect on a clear lineation; the text of pages 119–123 and the cross sections along the two glaciers concern details of these features. The lineations are far from horizontal and, on the whole, tend to plunge at angles between 20° and 45° . A study of the map shows that the direction of this plunge is constant. We have taken pains to explain that too much should not be deduced from the degree of plunge of lineation but that where the lineations are parallel to the hinge lines of the drag folds, as they very often are, they are highly significant of the regional tectonic trends.

If our text is read carefully it is hard to avoid the conclusion that the strata forming these schists have been very strongly *crumpled* with a maximum compression of the sequence roughly perpendicular to the trend of the Alpine Range. The lineations, the mesoscopic folds and the macroscopic (major) folds, that we were lucky enough to observe, all fit a consistent pattern of a B tectonic axis with trend parallel to that of the range.

When we published our original paper we were under the impression that we had considerably clarified certain structural features of the New Zealand Alpine schists *as seen in the field*, and discussed at some length the significance of these mesoscopic structures when mapped extensively. We considered that we had demonstrated not only the validity of mesoscopic structures in the mapping of larger units but also that neglect in studying these structures can lead to quite wrong interpretations of both the structure and stratigraphy. In a later cyclostyled journal (1958) I made some further comments on the last point. In all this work we used only methods long familiar in Europe and America and we arrived at results similar to those already achieved by many other writers abroad. Our results were consistent with the idea that locally, and locally only, schistosity and bedding planes could coincide over large distances; our results in other places were also consistent with the sort of data treated in petrofabric work on the Otago schists by Turner (1940) who had obviously worked in zones of considerable complexity such as we also observed; our work, however, was on the mesoscopic and macroscopic scale, his, largely on the microscopic scale.

Throughout our work we endeavoured to separate as much as possible purely descriptive matter from the conclusions which we drew *concerning one field only*.

We have not examined the field described by Wellman, Grindley and Munden (1952) so I am not competent to discuss their conclusions but it would appear that their study of smaller structures was less detailed than ours.

Dr Kingma, mentioning as evidence the papers by Wellman *et al.*, and by ourselves, stresses the postulated existence of two very different types of schists, comparing those of the Alps with those of Otago. Whilst the following observations were not contained in our joint paper it seems appropriate to comment on these generalisations. After examining the schists along the Haast Road and in many localities between Lake Wanaka and Taieri mouth I would not feel competent to draw any clear distinction between the different tectonic types to be seen in this field and those further north in the Central Alps. I have seen similar structures in rocks of similar metamorphic grade in both regions. On the whole it might be said that in chlorite and

biotite schists at the Fox Glacier the drag folds may show a more consistent pattern than in Otago, but there are many places in the Alps where this is not true. The only distinction that I would venture to draw, after four short seasons in the Alps and a short trip in Otago, concerns the attitudes of the microfolds (mesoscopic folds): in Central Otago these tend quite commonly to be recumbent, whereas in the Central Alps equally complex folds tend to have vertical or nearly vertical axial planes. Folded lineations have not yet been seen by us in the Central Alps but occur in Central Otago.

I would also suggest that in the Central Alps it is easier to observe clearly the B axis as represented by all its appearance, i.e., mesoscopic fold axes, mineral alignment in schistosity planes, rodding and other forms of lineation. From my very cursory examination of folds in Central Otago I should, at the moment, imagine the tectonics there to be more complex than in the Central Alpine regions; but, as every visit reveals more complexities in the Alps that may not be so.

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NOTE ON XONOTLITE FROM ACHERON RIVER, MID-CANTERBURY

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(Received for publication, 7 July 1959)

Summary

A chemical analysis and optical properties are reported for xonotlite occurring in veins in a teschenite sill at the Acheron River, Mid-Canterbury.

One of the writers (Lauder, 1953) has described a group of three laccoliths and three sills varying in composition from dolerite to picroteschenite, outcropping in the Acheron River area of Mid-Canterbury, and previously briefly reported by Speight (1928, pp. 42–45). They are emplaced in coal-measures of Upper Cretaceous age.

In the course of the work the hydrated calcium silicate, xonotlite, was encountered in noteworthy abundance in the largest of the sills, which outcrops on the south-facing bank of the Acheron River (S74/095742) a few chains down-stream from the coal mine, and again in the bed of the river near the mine mouth and near the top of the west bank 200–300 yd further north.

This is the first record of xonotlite from New Zealand. The mineral occurs in joints and shatter zones as aggregates of subparallel or radiating asbestiform fibres, forming masses of almost pure xonotlite up to $1\frac{1}{2}$ in. thick. The fibres are usually arranged approximately perpendicular to the walls of the veins which, however, are often slickensided or even brecciated, and sometimes show a slip-fibre structure. The colour is white on weathered surfaces but is otherwise the delicate pink often reported for xonotlite. The aggregates are tough and hard ($H=6$) and show a silky lustre. They contain a very small amount of intergrown calcite.

The X-ray powder diffraction pattern shows good agreement with that published by Schaller (1950) although with some extra lines including 100; 8.50 Å.

A chemical analysis (by J. A. Ritchie, Dominion Laboratory) and other properties are set out below:

SiO₂, 50.0%; R₂O₃, 0.1%; CaO, 46.5%; H₂O +, 2.96%; H₂O —, 0.2%; CO₂, 0.26%; Total: 100.02%.

Mr Ritchie reports that the loss of H₂O — at 107°C was quite distinct from that of H₂O +. Spectrographic determinations: Fe, 0.2%; Al, 0.02%; K, 0.02%; Mg, Na, Sr and Mn not significant.

Refractive Indices: γ (parallel to fibres) = 1.593 ± 0.002 .

$\beta \div \alpha = 1.584 \pm 0.002$.

Specific Gravity: 2.69 ± 0.01 (Determined by weighing in air and water. Equilibrium values were approached in water for specimens ranging from fine powder to compact, fibrous slabs several millimetres thick, after periods ranging from a few minutes to several weeks.)

After allowing for the CO_2 as 0.59% calcite, the chemical analysis leads to the empirical formula $\text{Ca}_{5.95}\text{Fe}_{0.01}\text{Si}_{6.02}\text{O}_{18} \cdot 1.19\text{H}_2\text{O}$, in satisfactory agreement with the structural formula $\text{Ca}_6(\text{Si}_6\text{O}_{17}) (\text{OH})_2$ (Mamedov and Belov, 1956). The slight excess of water is probably of little significance in such finely fibrous material, although it is to be noted that most analyses show still higher water contents.

Origin: Reported occurrences of xonotlite include contact metamorphosed limestones and dolomites (e.g. from Crestmore, California, described as jurupaite by Eakle, 1921; and Scawt Hill, Ireland, as noted by Tilley and Harwood, 1931); pegmatoidal veins in diabase (Schwartz, 1925); veins in the Franklin ore body, New Jersey (Palache, 1935); and veins near serpentine contacts (Kaye, 1953; Smith, 1954). Many syntheses of the mineral have been reported over the approximate range 160–400°C, xonotlite giving way to the more hydrous silicates of the riversideite-tobermorite group at lower temperatures and to wollastonite at higher temperatures (e.g. Heller and Taylor, 1951; Buckner and Roy, 1955). There is no reason to doubt that the present occurrence was deposited in a similar temperature range from solutions emanating from the teschenite sill itself in the post-magmatic stage, or from an underlying laccolith.

ACKNOWLEDGMENTS

The authors are grateful to the Dominion Analyst, and Mr J. A. Ritchie, Dominion Laboratory, Department of Scientific and Industrial Research, for the chemical analyses.

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ON A NEW KALENTERA (PELECYPODA: CYPRICARDIACEA) FROM THE UPPER TRIASSIC OF NEW ZEALAND

By J. A. GRANT-MACKIE, Department of Geology, University of Auckland

(Received for publication, 17 July 1959)

Summary

Kalentera marwicki n. sp. is figured and described. The holotype and other specimens are from beds of the Otapirian Stage (Rhaetian) near Awakino, south-west Auckland, and a number of specimens that seem conspecific are recorded from beds of the same age further north near Marakopa and Kawhia as well as in the Kaihiku Range, while the species is found together with *Monotis calata* of the Warepan Stage (Norian) near Marakopa. The form appears to be morphologically as well as stratigraphically intermediate between the Aratauran (Hettangian-Sinemurian) genotype *K. mackayi* Marwick and the Otamitan (upper Carnian) *Triaphorus zealandicus* (Trechmann) from which it probably developed. It is postulated that members of the family, formed part of the vagrant benthos in or on a shallow silty relatively flat sea-floor.

INTRODUCTION

The family name Kalenteridae was introduced by Marwick (1953) to accommodate the two new genera *Triaphorus* and *Kalentera* found respectively in the Triassic and Jurassic rocks of the New Zealand Hokonui System. So far neither group is known from Trias-Jura rocks outside New Zealand, but such is the overseas relationship of the Hokonui fauna as a whole that one can expect members of the family to turn up at least in some other part of the Papuan Geosyncline in rocks of Triassic or Jurassic age. The origins of the group are very uncertain, although affinities with Permian members of the genus *Pleurophorus* King, non Mulsant, (type: *Arca costata* Brown) are perhaps indicated. The arrangement of the cardinal teeth shows relationship with the Carditidae (Marwick, 1953). No mid Jurassic or later members or relatives of the family are known. The genus *Triaphorus* was erected for the shell Trechmann (1918) named *Pleurophorus zealandicus*, from South Island Otamitan (upper Carnian) beds, while *Kalentera*, possibly a descendant of this species, covers the forms *mackayi* Marwick, found in the Aratauran Stage (Hettangian-Sinemurian) of Southland, and *flemingi* Marwick, from beds on Awakino Valley Road, south-west Auckland, which Marwick (1953, p. 109) classed as Temaikan (Bathonian). The writer has shown, however, that these beds should be assigned to the upper part of the Ururoan Stage (Toarcian) since they contain *Spiriferina radiata* Hector and a rhynchonellid brachiopod found also at Ururoa Point, Kawhia Harbour (Grant-Mackie, in press).

In his review of the Otapirian Stage, Campbell (1956, p. 48) recorded *Triaphorus* sp. from beds of that age in the Kaihiku Range and near Kawhia. In the former area specimens came from beds Campbell correlated with the basal Otapirian, while in the sequence at Kawhia South Head, where a basal Otapirian fauna has not been recognised, it occurs beneath upper Otapirian faunas. In the Marakopa district Mr J. D. Campbell and Professor

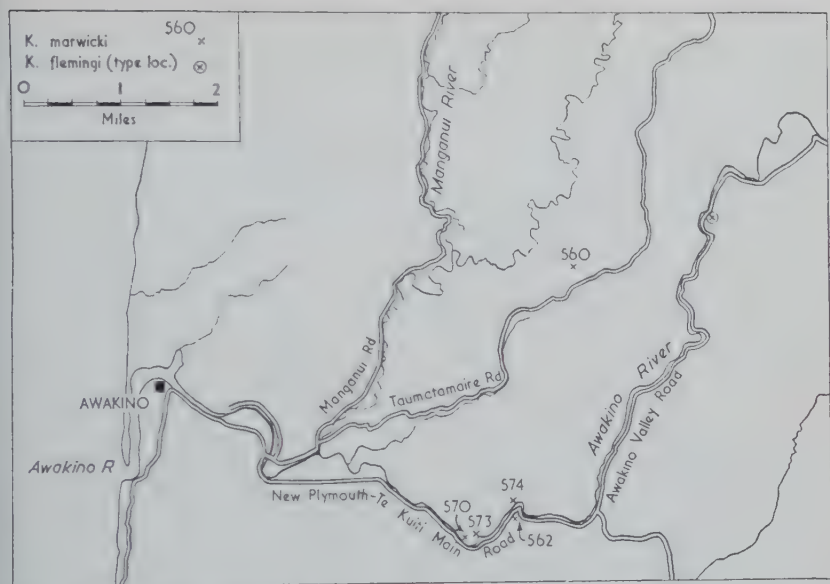


FIG. 1—Sketch-map showing distribution of *Kalentera* near Awakino (Sheet N91).

D. S. Coombs (pers. comm. J.D.C.) have collected specimens of a similar shell from two localities near the provisional base of the Otapirian sequence. Campbell (1959, p. 204) has also recorded *Triaphorus* from the type locality of *Monotis calvata* Marwick, of upper Warepan age (Campbell, 1959, p. 203; Grant-Mackie, in press). Further south near Awakino (fig. 1), similar shells were found in beds of mid and upper Otapirian age (Grant-Mackie, in press).

From the above it seems apparent that the Warepan-Otapirian shell may be more widely distributed than previously described forms (fig. 2). *Triaphorus zealandicus* has been recorded from the northern and southern parts of the South Island; *Kalentera mackayi* occurs in the Hokonui Hills, Southland; and *K. flemingi* is known from a single locality in the Awakino district (fig. 1).

OCCURRENCE

None of the members of the family occurs plentifully at any one locality. All have fairly heavy shells and specimens found are usually of closed individuals and infrequently of separate whole valves, entombed in fine-grained sediments (siltstones, silty mudstones, sandy mudstones, and shales), even the matrix of the Warepan shell-bed being a silt-stone, with pockets of comminuted shell debris and whole shells. The strata are generally rather thick massive beds, with little internal lamination and no evidence of grading or other features indicative of redeposition, nor have associated ripple-marks

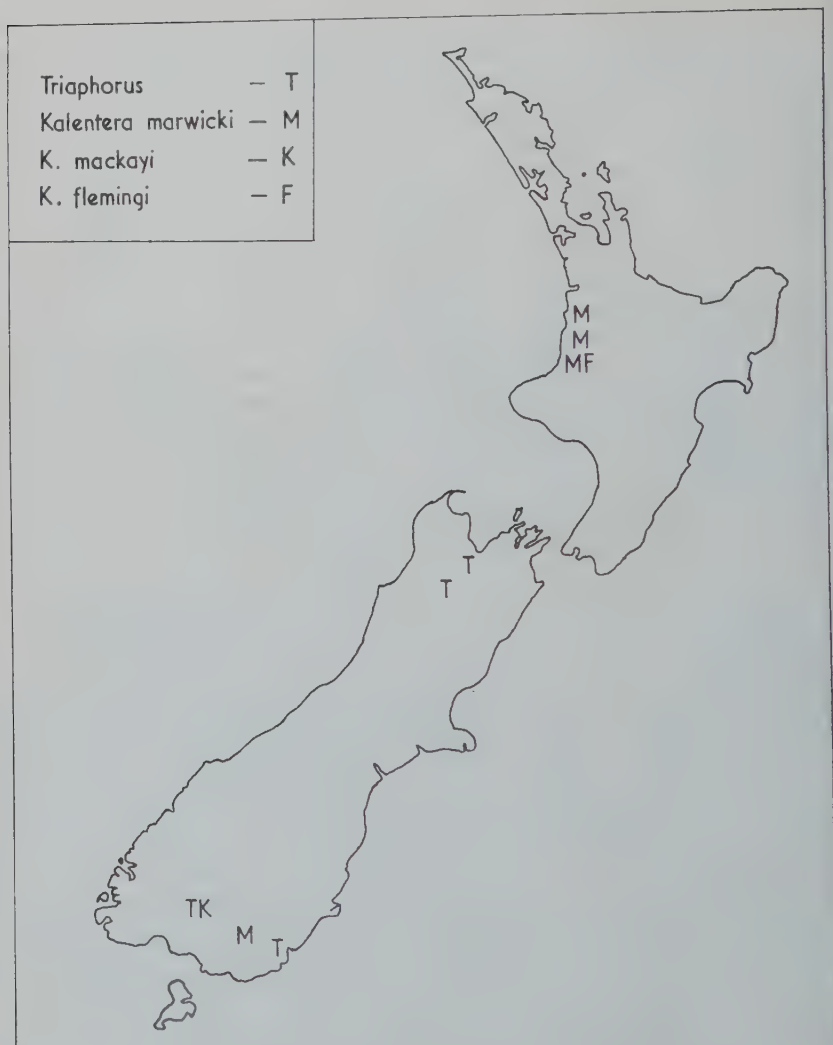


FIG. 2—Sketch-map showing known distribution of the Kalenteridae.

been recorded. Kalenterids collected by the writer have shown apparently random orientation within the strata and there has been no indication of well defined burrows.

These facts indicate that *Kalentera* and *Triaphorus* were members of a vagrant benthonic faunule and lived partly or wholly below the surface of the sea-floor in the soft uncompacted muds and silts of a relatively flat area of the sublittoral zone of the continental shelf with fairly uniform bottom conditions. The absence of burrows and the lack of any sign of a pallial sinus

on any specimens examined by the writer suggest that the animals lacked well developed siphons and may have been bottom feeders moving at random on or just below the surface of the ocean floor, in the manner of most modern venerids.

Associated fossils tend to support the above suggestions. The new form is found together with undescribed rhynchonellid and terebratulid brachiopods. *Spiriferina*, *Clavigera* and *Mentzelia*, the pelecypods *Pteria*, *Monotis*, *Otapiria*, *Chlamys* and *Anodontophora*, while pleurotomariid and trochid gastropods have also been recorded in association (see faunal lists in Campbell, 1956, p. 48, and 1959, p. 204; and Grant-Mackie, in press). *Triaphorus* is found with numerous other fossils including *Terebratula*, *Spiriferina*, *Nuculana*, *Palaeoneilo*, *Halobia*, "*Mytilus*", *Anodontophora*, *Pleurotomaria* and *Lepidotrochus*. *Kalentera mackayi* occurs with *Terebratula*, *Spiriferina*, *Nuculana*, *Otapiria*, *Entolium*, and *Pseudolimea*. *K. flemengi* is associated with rhynchonellid and terebratulid brachiopods, *Spiriferina*, *Palaeoneilo*, *Entolium*, *Grammatodon*, and the gastropod *Amberleya*.

The absence of oysters or *Gryphaea* (in common with most New Zealand Hokonui sediments) from the above assemblages indicates that the seas over the area of deposition were not markedly shallow. Associated brachiopods consist largely of types with a long hinge-line (*Spiriferina*, *Clavigera*, *Mentzelia*) which were probably partly buried, hinge down, in the soft bottom, and if this is so it suggests, along with the absence of ripple-marks, that currents were fairly slow and gentle. Other pelecypods either lived in much the same ways as did the kalenterids, or else, as in the case of the thinner shelled pteriids and pectinids, moved freely about and just above the surface of the sea-floor. The occasional cephalopod found (*Orthoceras*, *Cenoceras*, *Proclidonautilus*, *Rhacophyllites*) represents the pelagic faunule of the time entombed after death along with the more numerous benthonic elements.

PALEONTOLOGY

Only on some of the Awakino specimens has it been possible to examine the dentition of the valves, and the main criteria available for comparison of specimens from other areas have been shape and sculpture, and arrangement of the muscle scars.

The dentition of the Awakino shells is very similar to that in the figures and description of *K. mackayi* (Marwick, 1953), but the anterior cardinal of the left valve is situated anterior to the pedal retractor pit and seems to be more nearly vertical. In addition the beaks are smaller and more anterior in position, the posterior ridge is more rounded, the shell is less inflated and does not markedly widen posteriorly, the anterior adductor scar is smaller, and the pedal retractor pit deeper. As with *K. mackayi*, radials on the posterior area are irregularly developed and seldom well defined.

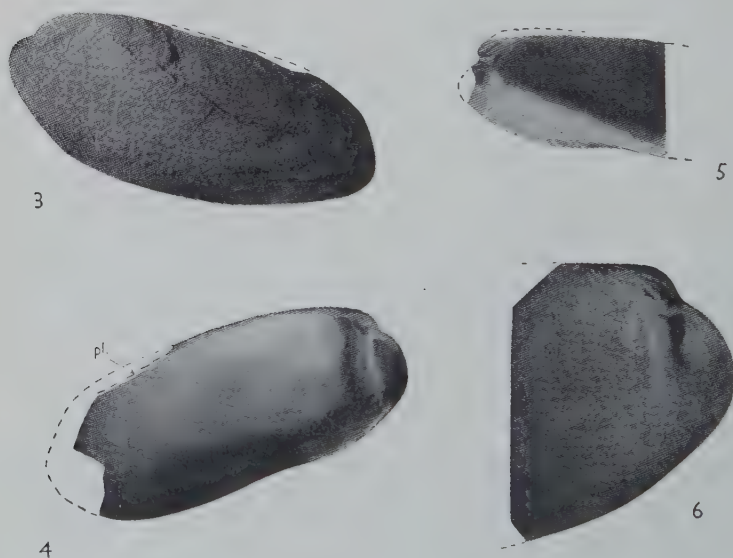
The hinge of *K. flemengi* is not known but the presence of sharp primary and secondary radial ridges together with the more broadly oval shape separates it from the Warepan-Otapirian fossils.

The shell is very similar in shape to *Triaphorus zealandicus*, although the beaks are more prominent and less anterior in position, the postero-ventral angulation is smaller, and the shell slightly less inflated. Internal characters,

however, serve to separate it from *Triaphorus*. The long horizontal anteriorly placed cardinal tooth of the left hinge of *Triaphorus* is absent and instead the shell has a nearly vertical triangular tooth. This, together with a bifid posterior cardinal in the right valve, a deeper pedal retractor pit, and a more anterior adductor pit, shows that the shell belongs to a new species of *Kalentera*, which genus is now known to range down to the Norian. While undoubtedly a *Kalentera*, the shell appears to be morphologically as well as stratigraphically intermediate between the Otamitan *Triaphorus zealandicus* and the Aratauran *Kalentera mackayi*.

Kalentera marwicki Grant-Mackie n. sp. figs. 3–6.

Shell of moderate size, transversely suboval, beaks subterminal; shell material relatively thick. Surface with fine irregular concentric striae and low rounded ridge trending postero-ventrally from umbo, disk anterior to



- FIG. 3—*Kalentera marwicki*, n. sp. Lochindorb-Rocky Dome track, Warepa S.D. (S179/589). Latex mould of exterior of left valve. $\times 1$.
 FIGS. 4, 6—*Kalentera marwicki*, n. sp. Awakino River bank, Awakino North S.D. (N91/573). Latex mould of interior of left valve (holotype). Fig. 4, $\times 1$ (pl = posterior lateral tooth); fig. 6, $\times 2$.
 FIG. 5—*Kalentera marwicki*, n. sp. New Plymouth-Te Kuiti main road, Awakino North S.D. (N91/562). Latex mould of interior of right valve. $\times 2$.

this somewhat flattened, posterior area flat or slightly rounded with 2 or 3 low distant rounded radials present on some shells, beginning a few millimetres behind beak and usually fading out about three-quarters of distance to posterior margin of adult shell. Lunule small, narrow, moderately impressed; escutcheon long, narrow. Anterior adductor pit of moderate size, situated only partly anterior to beak, bounded posteriorly by strong oblique

buttress which extends to hinge, widening slightly dorsally and having excavated in it below hinge plate small deep oval pedal retractor pit. Hinge plate narrow, curved; right valve with oblique deeply bifid posterior cardinal tooth situated antero-dorsal to pedal retractor pit; left valve with prominent triangular, almost vertical anterior cardinal tooth anterior to pedal retractor pit, long low narrow posterior cardinal parallel to dorsal margin of hinge, and long strong straight posterior lateral.

HOLOTYPE. The holotype is an internal cast of a left valve from N91/573 (figs. 4, 6) and will be presented to the New Zealand Geological Survey, Lower Hutt. The posterior and postero-dorsal margins of the cast have been broken away, and it has much of the external sculpture, including growth striae and two radial ridges, impressed upon it.

DIMENSIONS. Holotype: length, 48 mm. (estimated); height, 21 mm.; inflation, 6.5 mm. An external cast from Southland (fig. 3) has the following measurements: length, 47 mm.; height, 21 mm.; inflation, 5 mm.

LOCALITIES AND AGE. Cliff section between Ngutupuku Creek and Araitaura Point, Albatross Survey District (N73 2): anterior and antero-ventral fragment, probably conspecific with holotype (lower Bo). Coast, immediately above unconformity south of Kiritehere Stream mouth, Marakopa S.D. (N82 528): left valve and closed individual, each lacking posterior portion (top Bw). Coast, 57 ft stratigraphically above unconformity, Marakopa S.D. (N82/530): juvenile left valve and squashed individual (basal Bo). Coast, 100 yd north-east of unconformity, Marakopa S.D. (N82/534): part of squashed internal and external casts of one individual (Bo). Coast, 10 ch north-west of Kiritehere Stream mouth, Marakopa S.D. (N82.10): 3 internal casts of closed individuals (upper Bo). Cutting on track off Taumatamairi Road, Awakino North S.D. (N91/560): internal and external casts of individual (mid Bo). Awakino Valley Road, Awakino North S.D. (N91/562): 2 fragmentary internal casts (top Bo). North bank, Awakino River, Awakino North S.D. (N91.570): internal cast of closed individual (mid Bo). Seventeen chains upstream from N91.570, Awakino North S.D. (N91/573): holotype and 4 internal casts (mid Bo). Forty-five chains upstream from N91/573, and over river from N91/562, Awakino North S.D. (N91/574): fragmentary internal cast (upper Bo). Lochindorb-Rocky Dome track, Warepa S.D. (S179/589): external cast of left valve with dorsal margin of right valve (Bo).

The Kawhia material, and some of that from Marakopa was collected by Mr J. D. Campbell and Professor D. S. Coombs in February 1954. The remainder of the Marakopa specimens was collected by the writer in November 1958. Material from Awakino the writer collected between October 1955 and February 1956, and that from Warepa was collected by Mr J. D. Campbell in January 1955.

ACKNOWLEDGMENT

The writer wishes to acknowledge his indebtedness to Mr Campbell for the opportunity to study the specimens collected by himself and Professor Coombs.

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THE INCOMPETENT AND ELASTIC NATURE OF THE CHRISTCHURCH ARTESIAN SYSTEM

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(Received for publication, 12 May 1959)

Summary

The aquifers and aquicludes of the Christchurch Artesian System are moderately-to-highly incompetent and elastic, judged by the effects of ocean tides, of the changing water levels of Lake Ellesmere, and of earthquakes and passing heavy vehicles upon water levels in wells tapping them. The "outcrop" hypothesis advanced by Speight (1911) to account for the tidal effect is rejected in favour of one of loading.

INTRODUCTION

The Christchurch Artesian System is the name given to the artesian aquifers and aquicludes that extend from Christchurch City to Leithfield, 24 miles to the north, and to the south-west for 32 miles (fig. 1), having an area of approximately 350 square miles. The aquifers lie at depths ranging from 15 ft to more than 500 ft, and contain water under hydrostatic pressures ranging from a few inches to 30 ft of water. In general, the greater the depth to the aquifer, the greater is the hydrostatic pressure under which the water is confined.

The aquifers are composed of gravel and the aquicludes of interbedded clay, silt, and sand; they are of marine, estuarine, and fluvial origin. Suggate (1958) subdivided these deposits into the Christchurch Formation, Riccarton Gravel, and Bromley Formation, and assigned to them a late Pleistocene to Holocene age. The locations of the two wells that are discussed, one at North New Brighton, the other at Greenpark on the shores of Lake Ellesmere, are shown in fig. 1, and their logs are given in fig. 2.

Fluctuations of water levels in wells tapping these aquifers are caused chiefly by rainfall and by the pumping of adjacent wells tapping the same stratum, and to a lesser extent by changing rates of transpiration and evaporation. In New Brighton and probably in other coastal areas there is superimposed upon these fluctuations a semi-diurnal fluctuation produced by the oceanic tides. The water levels in artesian wells near the shores of Lake Ellesmere fluctuate with changes of lake level.

EFFECT OF OCEANIC TIDES UPON WATER LEVELS IN ARTESIAN WELLS AT NEW BRIGHTON

Previous Work

Before the turn of the century Hutton (1896, p. 655) made regular and frequent observations of the water levels in two artesian wells at the Canterbury Museum. When attempting to explain their fluctuations he compared

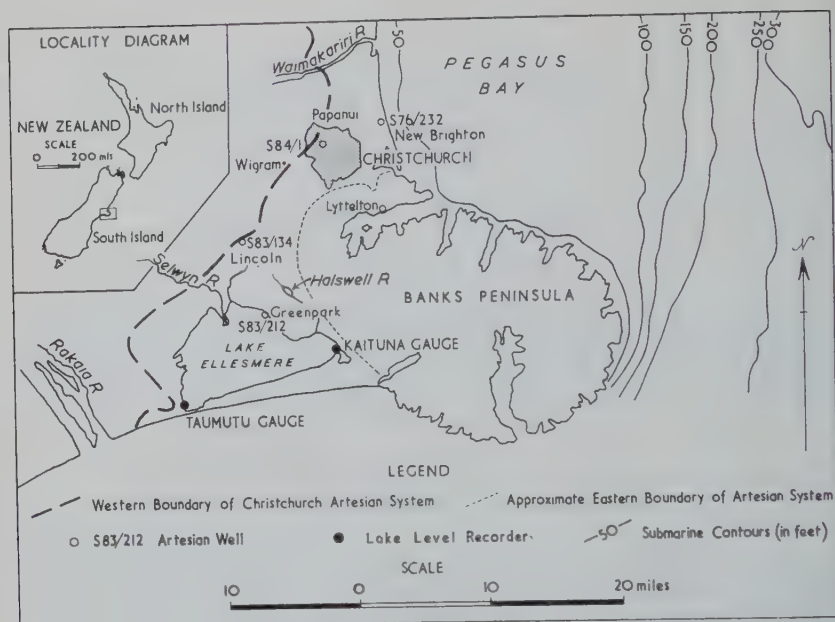


FIG. 1—Locality Map.

their hydrographs with the times of high and low tides at the coast $4\frac{1}{2}$ miles distant, but finding no correlation he concluded that the effect of the tides did not extend inland as far as the Museum. Speight (1911, p. 434) recorded the fluctuations of water levels in wells near the coast at New Brighton, noting that wells within three miles of the coast were affected by the tides, and that the magnitude of the fluctuations decreased with increasing distance inland. He considered the magnitude to depend also on the depth of the well, stating that in a well 144 ft deep the fluctuation was 18 in. between high and low tides, whereas in a well 280 ft deep a few yards away it was only 10 in.

Speight (1911, p. 435) considered that the aquifers are flat-lying and have submarine outcrops, and that the weight of salt water above these outcrops acts as a counterpoise that is almost as effective as impermeable beds in blocking the outflow from the aquifers. When calculating a theoretical example for a 144-ft artesian well at New Brighton, where the tide fluctuates over a range of 6 ft, he wrote: "We may suppose, therefore, that the water bearing stratum outcrops at an approximate depth of 144 ft below low water. Taking the specific gravity of sea water as 1.025, the length of a column of fresh water which would exactly balance this would be 144×1.025 — that is, 147.6 ft. So that a well sunk at the level of low water and supplied with a continuous amount of fresh water from inland would flow at about 3 ft above the surface." He explained the difference between the magnitudes of the tide and well fluctuations (i.e. between 6 ft and $1\frac{1}{2}$ ft)

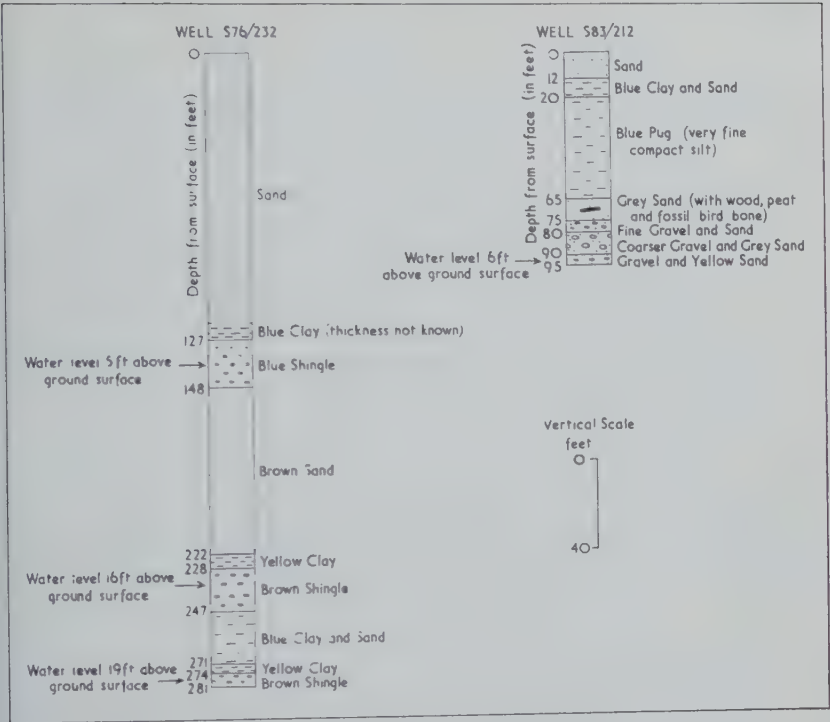


FIG. 2—Logs of two artesian wells, at North New Brighton (S76/232) and at Greenpark, Lake Ellesmere (S83/212).

as resulting from friction loss and the mixture of salt water with fresh water at the bottom of the well. "This mixture must take place owing to the disturbed conditions at the bottom of the well, due principally to the movement which must take place as the water is drawn off." Speight claimed that this explanation accounted for the admixture of salt water with fresh, in the case of wells near the shore, and also the falling off in saltness as well as in the tidal effect with increasing distance from the shore.

Speight's views have not been questioned by later writers although Hilgendorf (1926, p. 379) suggested, when discussing the pressure effect (loading) that, "This might account for some of the rise in coastal wells due to the rising tide, but the saltiness of the New Brighton wells is against the pure pressure explanation." Collins (1955, p. 30) accepting earlier evidence wrote: "The fact that the artesian wells of the Christchurch area fluctuate in response both to changes in atmospheric pressure and to changes in loading due to tides, floods, and moving weights shows that the aquifers and the aquicludes (the impermeable confining beds between the water-bearing strata) are neither perfectly rigid nor perfectly yielding."

Recent Work

The records from a continuous water-level recorder installed on a 281-ft well on the foreshore at North New Brighton in 1955, and again in 1957 (fig. 3) show that times of high tide coincide with times of high water level in wells. Observations of the tides on the beach confirm that the magnitude of the well water-level fluctuations varies directly with the heights of the tides:

that is, $h = kt$

when h = magnitude of the water-level fluctuation in an artesian well.

k = tidal efficiency, a constant.

t = magnitude of the tidal fluctuation over the same period.

The tidal efficiency is the ratio between the magnitude of the well fluctuation and the magnitude of the tide fluctuation, and at New Brighton is about 25%–30%, i.e. for a tidal fluctuation of 6 ft the water-level fluctuation in a

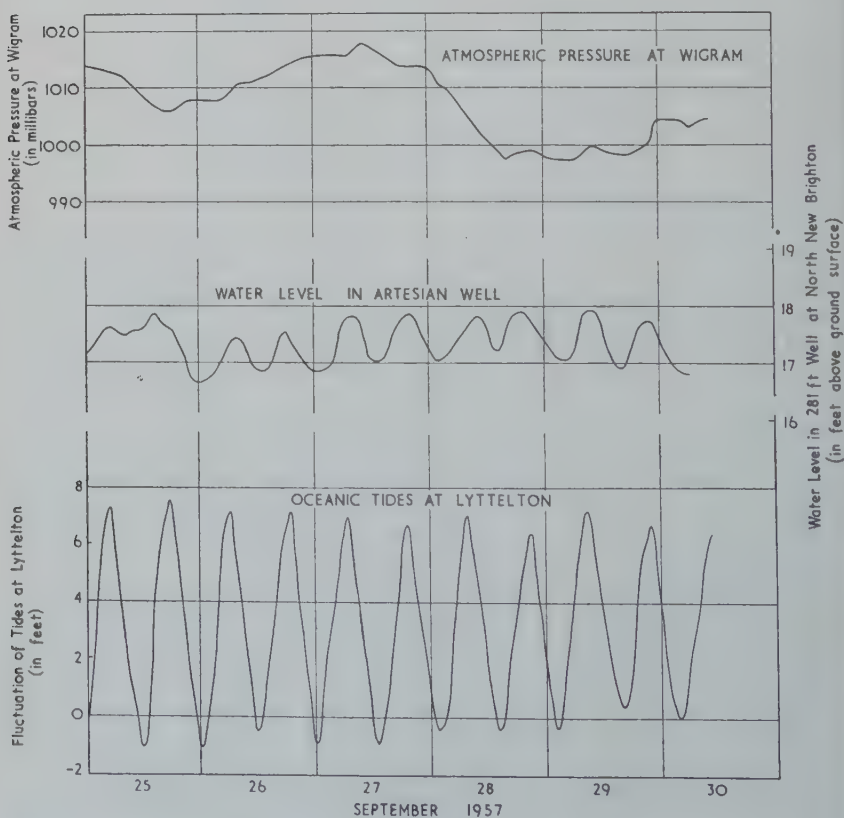


FIG. 3—Comparison of tidal fluctuations, atmospheric pressure changes and artesian-well water levels for the period 25 to 30 September 1957.

well is approximately 18 in. The largest fluctuation, 2 ft, was recorded at a spring tide. The records show also that there is no time lag between full tide and the highest water-level in the well.

For a week at the end of August and the beginning of September 1944, the Christchurch City Council recorded tidal fluctuations in their 450-ft artesian well at Kerrs Road, about $2\frac{1}{2}$ miles from the sea. The maximum fluctuation was 6 in. and peaks were reached 3 or 4 h after high tides. This supports Speight's observation that as the distance from the coast increases, the amplitude of the tidal effect decreases; and the suggestion that the time lag between high tide and high water levels in wells also increases with increasing distance from the coast.

The writer is of the opinion that Speight (1911) in postulating his theory and rejecting one of loading, was motivated by a need to explain the existence of salty water in wells 144 ft deep. There are now, however, many wells from 140 ft to 150 ft deep along the foreshore of New Brighton that do not yield saline water. It seems likely that the well or wells upon which Speight based his conclusions tapped one of the few beds in this area that yield highly mineralised water.

In recent years many wells have been sunk in the New Brighton area to tap the artesian aquifers that lie between 140 ft and 500 ft below the surface. Water-level observations in a number of these, within a $\frac{1}{4}$ mile of the shore, have shown fluctuations of between $1\frac{1}{2}$ and 2 ft that can be attributed to oceanic tides.

TABLE 1—Effect of tidal fluctuations on water levels in wells along the New Brighton foreshore.

Location of Well	Depth of Aquifer Below Ground Surface	Average Water Level (Above Ground Surface)	Well Water- level Fluctua- tion Due to Tides
	ft	ft	ft
Not known (cited by Speight)	144	3	$1\frac{1}{2}$
North New Brighton	281	19	2
New Brighton	300	13	$1\frac{1}{2}$ –2
South New Brighton	450	28	$1\frac{1}{2}$

Most of these observations were made by well sinkers, probably over short periods of time only, and as the date, time, and duration of the observation period is not known, it has not been possible to estimate the heights of the tides at the time. One explanation to account for the range of water-level fluctuations in these wells ($1\frac{1}{2}$ ft to 2 ft) is that the observations were made at different phases of the moon. Water-level records from the North New Brighton well showed that the average fluctuation due to tides was $1\frac{1}{2}$ ft, but at times of spring tides fluctuations of 2 ft were recorded.

These more recent well observations do not bear out Speight's statement that the amplitude of water-level fluctuations caused by tides are different for wells of different depths.

Speight's hypothesis to account for tidal fluctuation is not acceptable to the writer for several reasons:

1. Speight (1911, p. 435) acknowledges that on his outcrop hypothesis the water-level fluctuation in a well would be the same as that of the oceanic tides (6 ft) if there was no loss of head. He attributes the known difference ($4\frac{1}{2}$ ft) as due to:

- (a) Friction obstructing the rapid flow of water through the beds; and
- (b) Admixture of salt water with fresh water at the bottom of the well, which he says "... must take place owing to the disturbed conditions at the bottom of the well, due principally to the movement which must take place as the water is drawn off."

The loss of head caused by (b) can be neglected, because when water is being drawn off from a well the water level is necessarily lower than the static water level, and, therefore, true static level cannot be measured; after the withdrawal of water ceases the rate of movement of water in the well is very slow (about $\frac{1}{3}$ in. per hour, due mainly to tides) and the friction loss is negligible. This leaves the tidal efficiency to be explained by (a) i.e., by the frictional resistance offered to the flow of water in the aquifers. It is reasonable to assume that as the aquifers have similar cross sections, the actual loss of tidal head due to friction will depend upon the distance from their respective outcrops to the shore. These distances for the 144-ft and 281-ft aquifers, (assuming as Speight (1911) did, that the aquifers are flat), are 24 miles and 34 miles respectively (fig. 1). Recent work has shown that well water-level fluctuations due to tides are not smaller in the deeper aquifers, as Speight recorded them, but that fluctuations of between $1\frac{1}{2}$ ft and 2 ft have been recorded in wells tapping all the various aquifers from 144 ft to 450 ft.

2. Speight (loc. cit.) also stated that the water-level fluctuation in a 144-ft well near the coast was $1\frac{1}{2}$ ft, and that the tidal effect was not observed 3 miles inland. On this evidence, and assuming a gradual trend inland, there is a diminution of the fluctuation of 6 in. per mile. If the same rate of diminution of amplitude obtains landwards from the submarine outcrop as it does from the foreshore inland, the tidal effect from this cause (even when neglecting tidal efficiency) would not be effective closer than 12 miles off shore. On analogy with the cone of pressure relief of an artesian well, the width of the belt of pressure relief on a 6-ft fall of tide, or of increase on a 6-ft rise, is unlikely to be 24 miles for the 144-ft aquifer, or 34 miles for the 281 ft aquifer. It seems even less likely that the tidal effect in the deeper wells (e.g. 450-ft well) whose submarine outcrops would be more distant from the shore, could be explained in this way.

3. In his example to illustrate the tidal effect by the outcrop hypothesis, Speight (loc. cit.) considered a column of salt water 144 ft high supporting a column of fresh water 3.6 ft higher, and drew the conclusion that a well sunk to this depth would flow at about 3 ft above the surface. If these conclusions are valid for the aquifer 144 ft below the surface at New Brighton it is reasonable to expect that they would be valid for all the artesian aquifers underlying the New Brighton foreshore, and it should, therefore, be possible to calculate from the depths of aquifers the height to which water rises in wells tapping them. This cannot be done, however, as shown in table 2, and it must be assumed that pressures in the artesian aquifers, apart from those

causing periodic fluctuations, result from other factors, possibly the altitudes of their various intake beds.

TABLE 2—Water level in artesian wells along the New Brighton foreshore, as calculated on the outcrop hypothesis, and as observed in wells (taking the specific gravity of salt water as 1.025)

Approximate Depth of Aquifer Below Ground Level	Calculated Height of Water Level Above Low Sea Level	§ Calculated Water Level in Wells Related to Ground Surface, Assuming the Level of Well Site to be ca. 8 ft Above Low Sea Level	Observed Water Level Above Ground Surface
ft	ft	ft	ft
144	3.40	— 5	3
281*	6.83	— 1	19
300†	7.30	— 1	13
450‡	11.05	+ 3	28

4. The hydrostatic pressure near the outcrop of an aquifer would, on the outcrop hypothesis, rise and fall in phase with the oceanic tides, but away from the outcrop, maximum aquifer pressures would lag behind the tides because of the rate of growth of the area of pressure increase and the subsequent growth of the area of pressure relief with the changing tides. Also on the outcrop hypothesis, the outcrop of each aquifer would be at a different distance from the shore, and the water-level peaks in wells tapping any of the aquifers near the foreshore should occur at different times. Observation, however, has shown that high water levels in these wells coincide with times of high tide. This must mean that the fluctuations of the water-levels in these wells are in phase with the fluctuations of the tides, or that the peaks observed in the wells are caused by different earlier tidal peaks — a most improbable coincidence. As the tides and well water-level fluctuations are in phase on the foreshore, and out of phase by 3 or 4 hours in wells $2\frac{1}{2}$ miles inland, the tidal effect clearly cannot result from changes of hydraulic head on outcrops many miles out to sea.

The evidence available supports the suggestion that the rise and fall of oceanic tides cause the fluctuations of water-levels in wells in the New Brighton area, by changing the pressure on the sea bottom. The changing pressure is transmitted through the aquifers and their underlying and overlying beds, to more competent strata at depth. Within the aquifers themselves part of this pressure is borne by the rocks comprising the aquifer, and part by the artesian water under pressure. The changing pressure on the confined water is recorded as changing water levels in wells tapping the various artesian aquifers.

*North New Brighton.

†New Brighton.

‡South New Brighton.

§Speight based his calculations on a hypothetical well at low sea level. Most wells on the foreshore lie between 5 ft and 8 ft above mean sea level and this must be allowed for in calculating both the depth of the well below sea level and the static head above ground level.

THE EFFECT OF THE CHANGING WATER LEVELS OF LAKE ELLESMERE UPON
WATER LEVELS IN NEARBY ARTESIAN WELLS

Lake Ellesmere, 15 miles south-west of Christchurch, is roughly triangular, and has an area of about 100 square miles, and a maximum depth of 8 ft. It is separated from the sea by a spit 15 miles long, which tapers from a few miles wide at its eastern end to a few chains wide at its western end. The water level in the lake rises as water from the various in-flowing rivers and drains accumulates, until, when it has reached a predetermined level, the lake is drained artificially through a channel cut to the sea. The lake water is continually being redistributed by strong winds, which produce fluctuations of lake level of up to 18 in. As the shores of the lake are very flat this results in a significant areal redistribution of water, and the flooding of large areas of land.

Observations on a 95-ft artesian well near the lake shore at Greenpark have shown (when the effect of rainfall is disregarded) that water levels are high when lake levels are high, and low when lake levels are low.

No accurate lake levels are available for the Greenpark area but rough estimates of the height of the lake there can be made by interpolating from the records of the continuous lake gauges at Kaituna ($9\frac{1}{2}$ miles to the south-east) and Taumutu (10 miles to the south-west). These estimates can be made with confidence only on calm days, because both the strength and the direction of the wind exerts a strong influence upon the distribution of lake water. Two examples can be cited to illustrate the effect that a change of the water level in the lake has upon the well water levels.

- (i) On 24 March 1958 (fig. 4) a day after a drainage channel had been cut from the lake to the sea, the lake level was about 3 ft 5 in. above mean sea level and the water level in the artesian well was 4 ft $3\frac{1}{2}$ in. above ground level. Nine days later the lake had fallen 1 ft 8 in. and the water level in the well had fallen 2 in.
- (ii) On 22 July 1958 (fig. 5) when the lake level was about 4 ft 4 in. and the water level in the well 5 ft 6 in., a drainage channel was cut to the sea. On 15 August the lake had fallen by 3 ft to 1 ft 4 in., and the well water level by $5\frac{1}{2}$ in. to 5 ft $0\frac{1}{2}$ in.

Both the direction and velocity of the wind are significant factors in the redistribution of lake water, and so in the determination of the sense and magnitude of the movement of water in the well. In general, winds from northerly directions, which blow water away from the Greenpark shores, lower the water levels in the well, and winds from southerly directions raise it. Local landscape features and the configuration of the lake bed and shore line near the well site, however, also influence the relation between the wind and well water levels. To illustrate this latter, the wind directions and velocities, and well water levels recorded on 11 and 12 July 1958 are shown in fig. 6. The water level in the well was falling quickly from an unusually high level and would have continued to fall steadily had there been no wind. The wind blew from between 210° and 260° with velocities occasionally reaching 50 knots, and the movement of the lake water was towards the Greenpark side of the lake. The fluctuations of well water level that are superimposed upon the downward trend are attributed to the effect of the wind on the

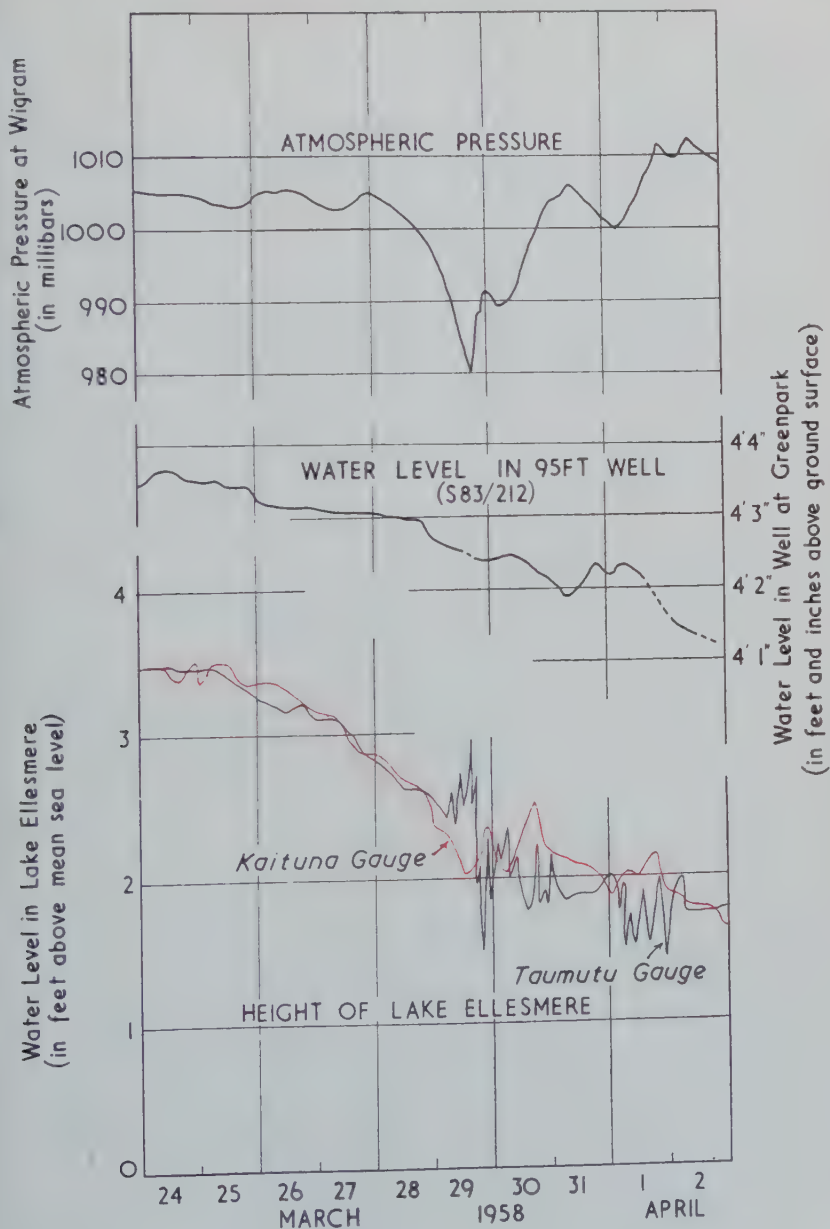


FIG. 4—Comparison of levels of Lake Ellesmere, atmospheric pressure changes and artesian-well water levels for the period 24 March to 2 April 1958.

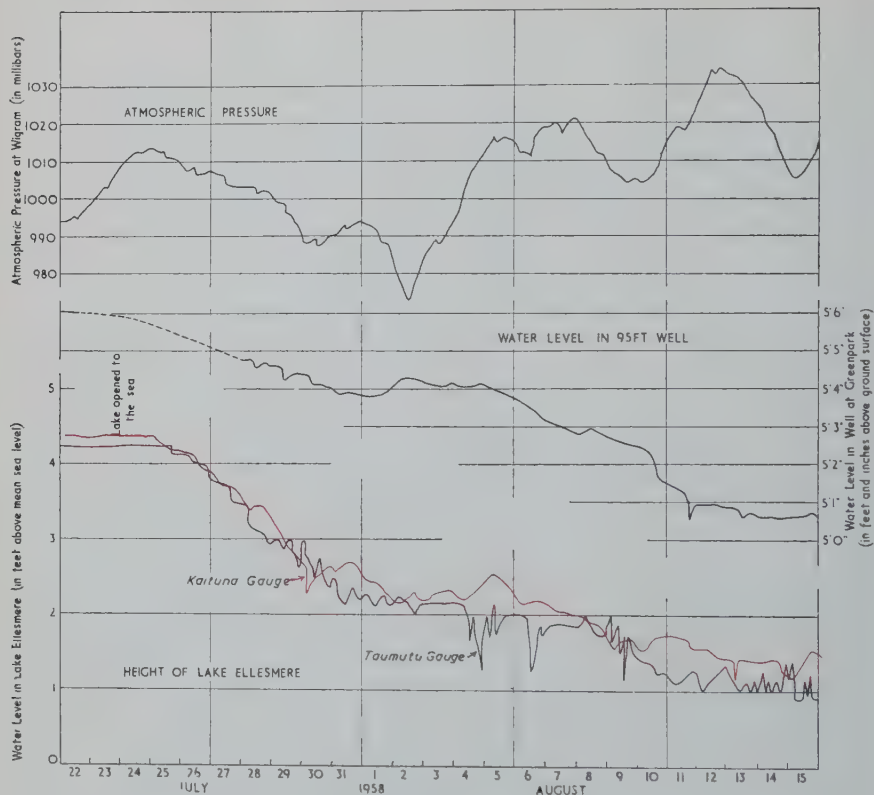


FIG. 5—Comparison of levels of Lake Ellesmere, atmospheric pressure changes and artesian-well water levels for the period 22 July to 15 August 1958.

lake water. These fluctuations are related more closely to small changes of wind direction than to changes of velocity. On the night of 11 July 1958 and morning of 12 July 1958 wind from 210° lowered the well water level despite a marked increase in velocity; the water levels began to rise when, later in the morning, the wind veered to 220° , and rose more rapidly when it was blowing from between 230° and 260° . On the night of the 12 July 1958 the water level fell steadily despite a swing to between 230° and 260° , because the velocity was insufficient to affect the lake water.

From these, and occasional observations on other wells, it is reasonably certain that the water levels in all artesian wells around the lake:

- (i) Rise as the lake level is raised by accumulation of water, and are lowered by the subsequent draining of the lake.
- (ii) Are raised and lowered by the accumulation and removal of lake water that results from the action of strong winds.

The relation between the changes of level of the lake and the corresponding well water-level fluctuations (tidal efficiency) cannot be determined accu-

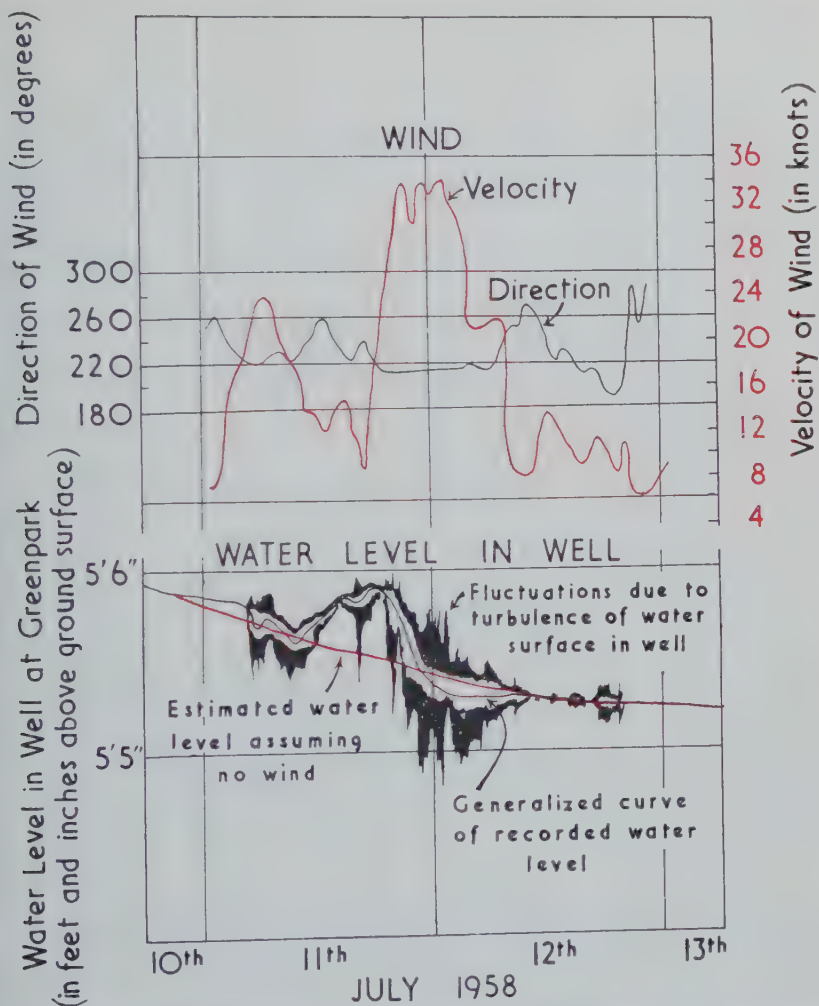


FIG. 6.—Comparison of wind directions and velocities with artesian-well water levels. The curve suggested as the one the water level would have followed if there had been no wind, is based on the normal die-away curve of the well. The broad zone of fluctuations on the water-level curves is caused by excessive turbulence of the water on which the recorder float was floating; the generalised curve is drawn to facilitate interpretation.

ately because of the lack of accurate lake level data, but is estimated to lie within the range 15–25%, comparable to that obtained for wells at New Brighton.

The correlation between water levels in the lake and in the artesian well near the shores of the lake can be attributed to the lake water loading the artesian aquifer adjacent to the well.

THE EFFECT OF CHANGING ATMOSPHERIC PRESSURES UPON WATER LEVELS IN ARTESIAN WELLS TAPPING THE CHRISTCHURCH ARTESIAN SYSTEM

Previous Work

When discussing water-levels in wells in the Christchurch area, Speight (1911, p. 432) referred to barometric pressure as having an undoubted effect on the flow of wells (and hence presumably upon the water levels in the wells, as water levels and flows in any one well are directly related). Hilgendorf (1912, p. 150; 1926, p. 375) described observations that had been made in the Greenpark and Lincoln districts, about 15 miles south of Christchurch, and discussed the relation between water-level fluctuations in wells and changes of barometric pressure, which he said (1926, p. 376) "... were differently developed in different wells. The Lincoln College well (344 ft) rises four times as much as the barometer falls, but a nearby well of 60 ft in depth showed a water-rise only equal to the barometer-fall." He illustrated a hydrograph of an 80 ft artesian well at Greenpark and a barogram taken at the same time, and commented upon their similarity. He was convinced that the barometric effect at Christchurch must be quite striking, but was unable to detect it because of the interference effects between wells.

Recent Work

Hydrographs recorded during parts of 1955 and 1957 from a continuous water-level recorder on a 281-ft artesian well at North New Brighton, and others taken at 95-ft artesian well at Lake Ellesmere in 1957-58, have been compared with barograph records for Wigram.* (figs. 3, 4, and 5.)

The writer has not been able to find in recent work any correlation between well water-level fluctuations and atmospheric pressure changes. At a few selected times on various records it is possible to recognise what may appear to be a correlation, but when records from a longer period are studied it is apparent that these must be regarded as fortuitous.

THE EFFECT OF EARTHQUAKES AND PASSING HEAVY VEHICLES UPON WATER LEVELS IN ARTESIAN WELLS TAPPING THE CHRISTCHURCH ARTESIAN SYSTEM

Earthquakes can produce temporary or permanent changes in water levels in wells. The magnitude of the fluctuations that are produced in artesian wells reflects the magnitude of the earthquake experienced at the well site; the time at which the water level starts to fluctuate coincides with the time of arrival of the earthquake waves. The hydro-geological effects of an earthquake are widespread. Parker and Stringfield (1950, table 1, p. 457) related fluctuations of water levels in artesian wells in Southern Florida, U.S.A., with an earthquake which had occurred 49 min. earlier at its epicentre, between Aus-

*Mr J. A. Hunter (pers. comm.) of the New Zealand Meteorological Service is of the opinion that there is no significant pressure gradient over the Christchurch area, and that the Wigram pressures can be accepted as rarely differing by more than about 0.5 millibar (0.1 to 0.02 in.) from those elsewhere in the Christchurch area.

tralia and New Zealand. The artesian aquifers are alternately compressed and dilated as earthquake waves pass through them, and this causes water levels in wells tapping them to rise and fall. Usually it is the L wave that is recorded but the other waves can also be recorded with a sensitive water-level recorder having a suitable time base (Vorhis, 1955, p. 49).

The effect of one earthquake was recorded in Canterbury by Mr L. P. Symes in August 1917 (Hilgendorf 1926, p. 379). No doubt earthquakes have on many later occasions affected water-levels in wells tapping the Christchurch Artesian System but the effect has not been recorded.

Water-level fluctuations somewhat similar to those caused by earthquakes, but of smaller magnitude, are produced by passing heavy vehicles. One such fluctuation was recorded in Christchurch by Symes (1917, p. 495), who observed a rise in water level in a well at Papanui as a heavily laden water tram passed some 30 ft from the well.

THE INCOMPETENT NATURE OF THE CHRISTCHURCH ARTESIAN SYSTEM

The addition or removal of water from above ocean or lake floors can affect water levels in artesian wells only when the aquifers and their overlying beds can transmit to the confined water, pressure exerted on them. Loading forces, unlike those exerted by atmospheric pressure, act on the aquifers only, and not also upon the water surfaces in the wells. When loading is applied, the hydrostatic pressures in the aquifers increase and the static water levels in the wells rise until equilibrium is attained. A continuously changing loading force, as that exerted by the ebb and flow of oceanic tides causes a corresponding, continuously changing water level in those wells close enough to be affected.

For the pressure from the overlying beds to be transmitted to the water within the aquifer, it may be presupposed that either the aquifers and confining beds are capable of being deformed, and hence are incompetent to resist a change of shape, or that the ocean or lake waters, and the aquifers, are in effective hydraulic contact. The evidence that earthquakes and passing heavy vehicles cause water levels in wells to fluctuate supports the hypothesis that the beds are incompetent. Their degree of incompetency can be judged by comparing the tidal efficiencies of the aquifers at North New Brighton with those overseas. The highest tidal efficiency recorded in Florida, U.S.A., is 50%, and this was reported from both the Gulf of Mexico (Stringfield, 1933, p. 163) and Atlantic Ocean (Stringfield, 1936, p. 141). sides of the peninsula. Warren (1944, p. 74) reported artesian aquifers near the Tybee lighthouse on the south-eastern coast of Georgia, U.S.A., as having a tidal efficiency of 50%, and those in other parts of the Georgian Coast as having values ranging from 20% to 50%. Thompson (1928, and quoted by Meinzer, 1928, p. 273) reports fluctuations due to tides on a well, at Longport, New Jersey, U.S.A., as ranging from 1 ft to 3 ft at different times of the month, and representing a tidal efficiency of a little more than 50%. Stevens (1956, p. 152) showed that water levels in wells tapping the Hutt Valley Artesian System fluctuate with oceanic tides by amounts proportional to the distance of the wells from the sea, and that the time lag between high tide levels and high water levels in the wells increases with

increasing distances from the sea. The explanation Stevens offers for this tidal effect is, "The sea acts as a dam on the flow of underground water. . . ." The artesian system extends (Stevens, 1956, p. 150) to about two miles south of Soames Island, i.e., about four miles from the shore. Water levels in a well 0.1 miles from the shore fluctuate 2 ft (from Stevens, 1956, fig. 4, p. 154 there is a fluctuation of water level in the well of about 1.75 ft with a 4.25 ft fluctuation of tide); 2.2 miles inland they fluctuate 3 in. The time lag increases from 12 min., 0.1 miles from the shore, to 45 min. 1.0 miles further inland. The arguments used in support of loading as the probable cause of the tidal effect in the Christchurch Artesian system can be applied also to the Hutt Valley Artesian System. If the loading hypothesis is accepted, the ratio between the tides and well water levels can be regarded as the tidal efficiency, i.e., approximately 40%.

The lack of correlation between atmospheric pressure changes and water levels in wells tapping the Christchurch Artesian System provides additional support to the hypothesis of the incompetent nature of the aquifers, because in this case not only is the atmospheric pressure exerted on the water surface in the well, but it is also transmitted through the overlying beds to the water confined in the aquifer, and the two pressures tend to cancel each other out. They do not do so exactly because the tidal efficiency is not 100%, but the resultant pressure differences are reduced so much that they cannot readily be detected among the many other minor fluctuations of water levels in wells.

THE ELASTIC NATURE OF THE CHRISTCHURCH ARTESIAN SYSTEM

The static heads of the various aquifers in the Christchurch Artesian System declined from 1858, when the first artesian well was sunk, until the turn of the century. Since then the static heads have ranged between lower, but stable, limits. This stability is shown by a comparison of maximum and minimum water levels, observed in a 340-ft well (S83/134) at the Canterbury Agricultural College, Lincoln, during two periods, from 1912 to 1917 and from 1945 to 1950. In these periods the water in the well reached some of the highest and lowest levels recorded in the 43 years that periodic observations have been made. The highest level in the 1912-1917 period was 11 ft 1½ in. (on 6 October 1912) and the lowest was 3 ft 0 in. (on 17 March 1917) above ground level. In the 1945-1950 period the highest level was 11 ft 3 in. (on 15 October 1945 and this is the highest that has ever been recorded in the well) and the lowest was 3 ft 0¼ in. (on 6 March 1950) above ground level. Thus there is no evidence of a continuous lowering of water levels that could be taken to indicate compaction of the aquifers. The water-level fluctuations in the well can be correlated closely with rainfall, and the long term trends with rainfall trends, as shown in fig. 7.

The absence of a long term decline of static heads, together with the evidence provided by the rates of recovery of wells after pumping (which range from minutes to hours depending upon the permeability of the aquifer tapped and the drawdown before pumping ceased) gives an indication of the elastic nature of the aquifers and their confining beds.

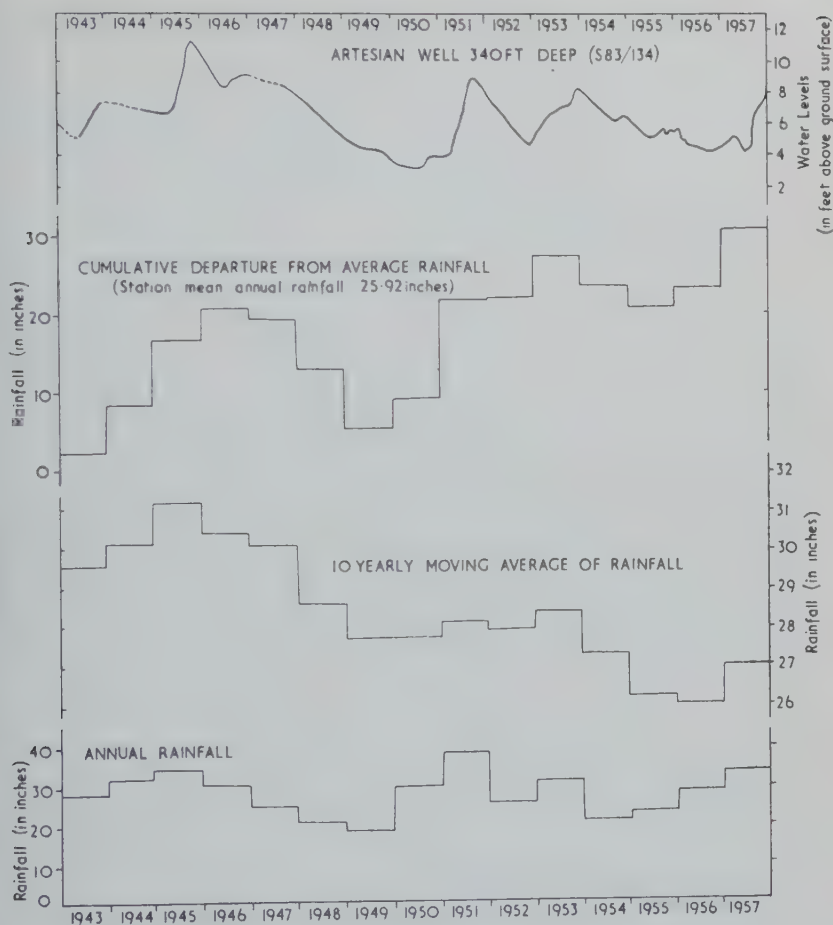


FIG. 7—Comparison of water levels in an artesian well and rainfall, at Lincoln.

CONCLUSIONS

The conclusion that the aquifers and aquicludes of the Christchurch Artesian System are moderately-to-highly incompetent and elastic is based on:

- (1) The coincidence of times of high water level in wells on the New Brighton foreshore and oceanic tides at New Brighton, contrasted with the time lag observed in wells a few miles inland.
- (2) The coincidence of times of high water levels in a well at Greenpark and high levels of Lake Ellesmere in the Greenpark area.

- (3) The tidal efficiency of up to 30% for all aquifers at New Brighton.
- (4) The effect of earthquakes and passing heavy vehicles on water levels in wells.
- (5) The lack of evidence from wells tapping any of the various aquifers in the system, of a continuous lowering of water levels which could be taken to indicate compaction of the aquifers.
- (6) The lack of correlation between well water-level fluctuations and atmospheric pressure changes.

ACKNOWLEDGMENTS

Use has been made of meteorological, lake-level, and well water-level data collected by many people, and the writer wishes to thank the N.Z. Meteorological Service, the Canterbury Agricultural College, Lincoln, the North Canterbury Catchment Board and the Christchurch City Council for making these available. The writer is indebted to Mr A. B. Clemence for the log of the North New Brighton well, and to Mr W. D. Shennan for that of the Greenpark well. Especial thanks are due to officers of the Department of Agriculture for attending water-level recorders at their Saline Soils Trial Area at Lake Ellesmere, and to colleagues at the N.Z. Geological Survey for reading and criticising the manuscript.

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BORON IN SOME NEW ZEALAND GROUND WATERS

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Summary

Analyses of some New Zealand ground waters are examined in relation to the origin of their boron. In the Waikato district only warm ground waters are significantly enriched in boron. These probably derive most of their heat and some of their salt content from volcanic sources,

The boron/anionic equivalent ratios of thermal waters in the Rotorua-Taupo region bear no relation to the dominant anion present or pH values, but increase south-westerly towards Tongariro National Park.

Increasing boron content of thermal waters appears to be associated with increase in basicity of associated volcanism. There is no proof for either a leached or primary magmatic origin for boron.

INTRODUCTION

The origin of the relatively high boron content of Waikato coal ash is discussed by Kear and Ross (in preparation). As part of this investigation, ground water samples were collected throughout the Waikato and neighbouring regions and were analysed for boron. These showed that only warm waters, considered to be partly of hydrothermal origin (see later), contained a significant amount of boron. This discovery led to investigation of the distribution of boron in the hydrothermal waters of the Rotorua-Taupo graben and elsewhere in New Zealand. This paper thus consists of two parts, viz.: "Boron in Waikato Ground Waters", and "Boron in Thermal Springs of New Zealand".

Boron contents of the Waikato ground waters are from unpublished analyses by Mr S. H. Wilson and Mr K. M. Griffin of the Dominion Laboratory. The remainder are mostly from Grange (1937). The Ngawha analyses are from Fleming (1945); those for Te Aroha from Henderson (1938), and from Dominion Laboratory reports (1921). Analyses for Helensville (1), Hanmer (1), Ketetahi (1), Rotorua (2), and White Island (2) were obtained from an unpublished report by Mr J. Healy, New Zealand Geological Survey, Rotorua.

BORON IN WAIKATO GROUND WATERS

All analyses shown in table 1 are of ground waters in the Hamilton Lowlands except those classed as coming from "surface" and those from basaltic aquifers, which were collected from the Pukekohe region. The "surface" water consisted of a sample collected towards the end of summer from a small, trickling stream within greywacke, overlain by a small amount of vol-

canic ash. This table shows that waters with outstandingly high amounts of boron are warm ground waters from the older Pleistocene sediments. Not only do these waters contain more HBO_2 than others, but their percentage of HBO_2 in total solids is also the highest.

TABLE 1—Boron in Waikato Ground Waters

Aquifer	No. of Samples	HBO_2 (p.p.m.)	% HBO_2 in Total Solids*	Analyses No.
Peat	1	1.0	0.38	N65/w503
Basalt	4	.....	less than 0.1	N47/w501-504
Hinuera Formation	3	0 to 1.6	0 to 0.48	N56/w500-501; N65/w501
Older Pleistocene—				
(a) Cold	4	0.1 to 0.9	0.75 to 1.1	N65/w500-502; 506
(b) Warm	4	21.5 to 112.0	2.7 to 6.2	N56/w503-504; N65/w504-505
Surface (greywacke rocks)	1	0.17	0.31	N56/w502

The heat in the warm ground waters may be acquired from recent tectonic movements or from a magnetic body at depth. Recent geological surveys confirm Marwick's (1948) observations that there have been no major tectonic movements for this part of New Zealand since the Miocene. Thus the heat is most likely derived magmatically. Additional evidence is provided by the salt content of these warm waters. The Cl-Mg ratios of two warm ground waters in the Hamilton Lowlands suggests that they are sea-ground-waters (Schofield, 1956) but the more recent analyses of samples N56/w503, N56/w504, N65 w504, and N65 w505 include bromine determinations and thus both ratios of Cl-Mg and Cl-Br (Schofield, 1956) provide a check on the origin of the salt content. These more recent analyses (to be published in a Geological Survey bulletin on the ground water of the Hamilton Lowlands) suggest that a magmatic origin for their salt content is most likely. However, it does not necessarily follow that the high boron content is also of magmatic origin, as the boron may equally well have been leached from boron-containing rocks by hot ground water.

BORON IN THERMAL SPRINGS IN NEW ZEALAND

Figs. 1 and 2 show the distribution of thermal springs and their average boron content expressed as ratio of HBO_2 (p.p.m.) to anionic equivalents. The greater number are in the Rotorua-Taupo graben (fig. 2). Some comparative method of giving the boron content, other than in p.p.m., is required as hydrothermal waters may be more dilute in some localities than in others. The ratio of boron compounds to total solids is not satisfactory for two reasons: (a) the different reactive weights of different anions and cations; and (b) the total solids may include organic remains. A better ratio for comparative purposes would be one of some boron compound with the equivalent weights of total dissolved solids. A simpler ratio is HBO_2

*This ratio is used instead of HBO_2 (anionic equivalents (see later)) as not all analyses were complete.

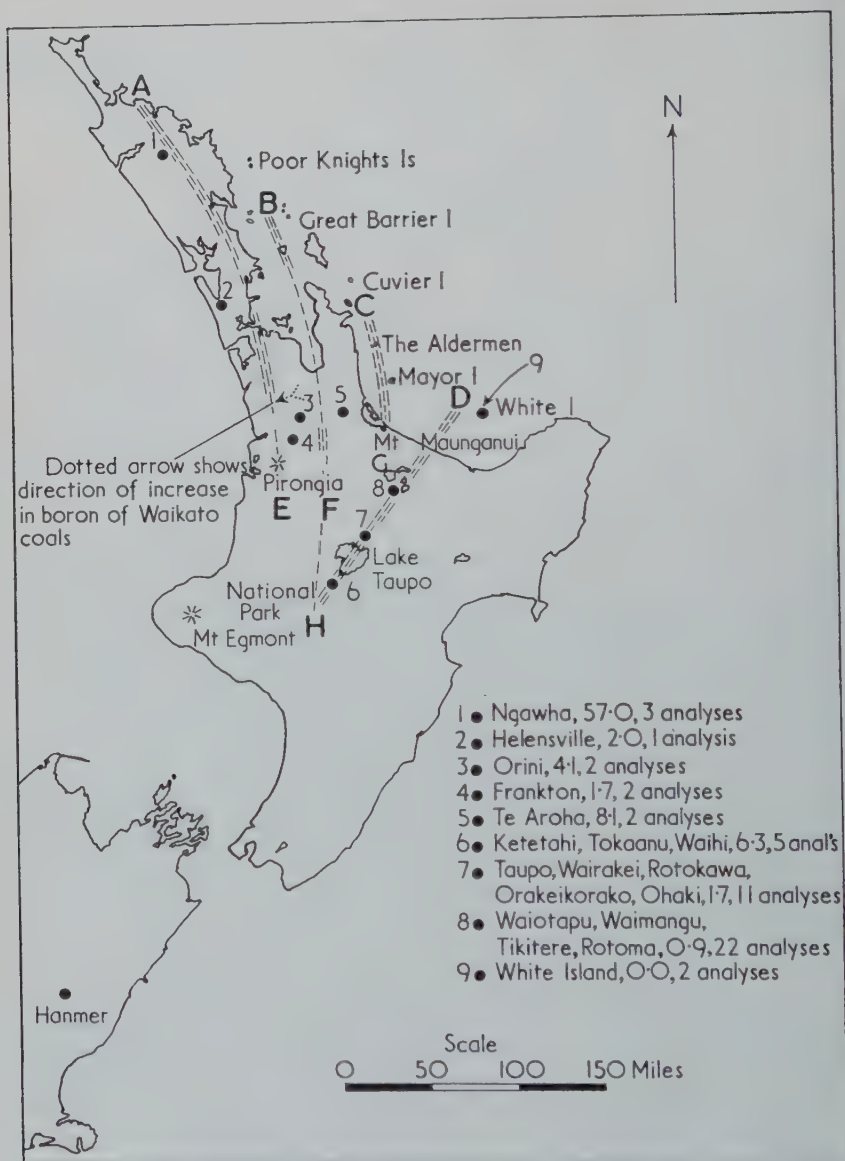


FIG. 1—Distribution of average HBO_3 (p.p.m.)/anionic equivalent ratios for hot springs and warm ground waters (for further details of distribution in the Rotorua-Taupo graben see figs. 2 and 3); and distribution of basaltic (AE), andesitic (BFH), acidic (CG), and mixed (DH), Quaternary volcanic zones. Note: Since this figure was prepared, additional information (Kear, pers. comm.) shows an easterly enrichment of boron in coal west of zone AE.

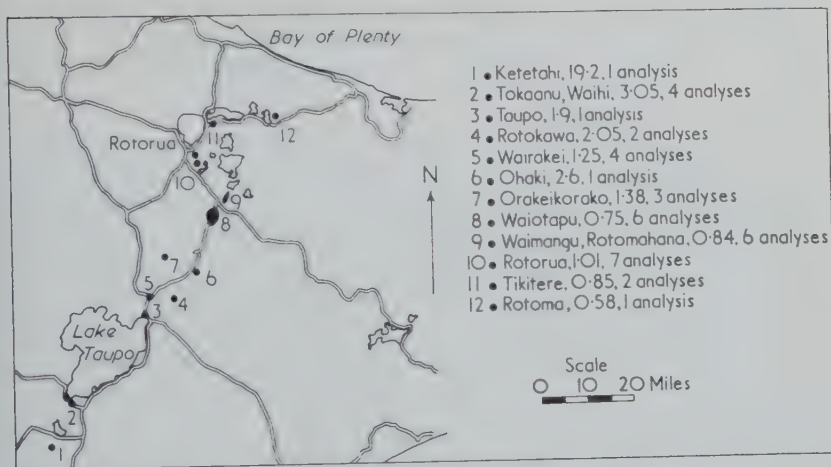


FIG. 2.—Distribution of average HBO_2 (p.p.m./anionic equivalent) ratios for hot spring centres within the Rotorua-Taupo graben.

(in p.p.m.) to the equivalent weight of the anions, for the latter must balance the equivalent weights of the cations. The HBO_2 /anionic equivalent ratio for each water within the Rotorua-Taupo graben is shown in the graph of fig. 3. This graph shows a distinct decrease in the HBO_2 content of the thermal waters in a direction from Ketetahi Springs, Tongariro National Park, to White Island. It also shows that there is no relation between the acidity or type of a thermal water and its boron content.

Outside the Rotorua-Taupo graben area there are not sufficient boron analyses to allow generalisations. However, there are two interesting results. The hydrothermal area of Ngawha (Fleming, 1945) contains springs richer in HBO_2 than any others yet analysed in New Zealand. The average HBO_2 /anionic equivalent ratio is also by far the highest. The other interesting result is the high HBO_2 /anionic equivalent ratio for the hot springs of Hanmer in the South Island, where there has been no surface volcanic activity.

ORIGIN OF BORON

There are two possible sources for boron in ground waters: either leaching from the associated rocks, or primary-volcanic origin. Neither Goldschmidt (1954) nor Clark (1924) was able to reach any conclusion on this problem. The former wrote: "In many such cases the presence of boron compounds in pegmatites, contact zones, and plutonic and volcanic exhalations has been considered by earlier observers to be evidence of igneous magmas being the sources of boron compounds. However, present knowledge of the geochemical distribution of boron clearly demonstrates its relative abundance in sea water and many marine sediments, as compared with the general scarcity of the element in igneous rocks. Therefore, when boron occurs in marginal zones of igneous rocks, in exhalations, and in thermal waters, we must consider whether the original source of the boron should be sought in

the igneous magma, or perhaps rather in adjacent marine sediments. The boron in sedimentary rocks, for instance in marine shales, has been 'mobilised' or 'mineralised' in a number of cases by the thermal action of igneous magmas."

Volcanic Origin

The boron content of thermal waters at Ngawha where the underlying magma is basalt (Fleming, 1945) is much greater than at Ketetahi and Tokaanu where the thermal activity is due to an underlying andesitic magma (Healy, 1943). The boron contents of thermal waters in these areas are in turn greater than those in the dominantly rhyolitic areas of the Rotorua-Taupo graben to the north-east. Thus there appears some correlation between a westward increase of boron and the westward change from acid to basic volcanic zones of Quaternary age in the northern half of the North Island (figs. 1 and 3).^{*} However, such a correlation may be also used as an argument for a leached origin (see below).

The almost complete absence of boron analyses for igneous rocks in New Zealand is unfortunate. An examination of analyses from overseas seems to show no direct relationship of boron content to the different types of igneous rocks. Goldschmidt (1954) showed that plutonic rocks – granites, gabbros, and nepheline syenites – contained similar averages of 10 p.p.m. B_2O_3 , whereas volcanic rocks range from 5 p.p.m. B_2O_3 in basalts and pantellerite (a peralkaline rhyolite) to as high as 100 p.p.m. B_2O_3 in liparite (a sub-aluminous rhyolite). Analyses are few and uncertain (Goldschmidt, 1954) but at the moment there appears no geochemical trend that might explain a primary origin for the apparent increase in boron in exhalations from more basic magmas.

Leached Origin

Hot waters may derive their boron during their rise to the surface, by leaching the country rock. This possibility is best shown by boron-containing waters found in regions where there is no surface volcanic activity. For example Healy (unpublished N.Z. Geological Survey report) considers that crustal upheaval, accompanied by an abnormal rise in isogeotherms, is the origin of the heat for the bulk of the South Island springs including those at Hanmer. He also states that at Hanmer the waters contain "borate and it was formerly considered that on this account the waters might be magmatic in origin. However, recent chemical analyses of rocks of the older greywackes from various localities [see Reed, 1958, p 40] show that

^{*}The Quaternary age of basalts of the Northland, Auckland, and Bombay regions, and the olivine andesites and basalts of Pirongia (zone AE) is very well established both from volcanic form (Kear, 1957) and stratigraphic position. The andesites of Little Barrier Island, at the northern end of zone BFH are considered Late Pleistocene by Kear (1957). North of F in this zone the little eroded forms of the andesite cones, Maungatautari, Kiwitahi, Te Tapui, and Maungakawa also show that they are of Quaternary age. The residual mountain of Maungatapu near Morrinsville, lies within this zone and could be early Pleistocene. The only volcanoes known to be of Quaternary age in arc CG are Mayor Island (Brothers, 1957) and Mount Maunganui. No definite ages for the volcanics in the Coromandel Range can be given, but it is probable that volcanicity of Quaternary age was mainly confined to rhyolites and ignimbrites.

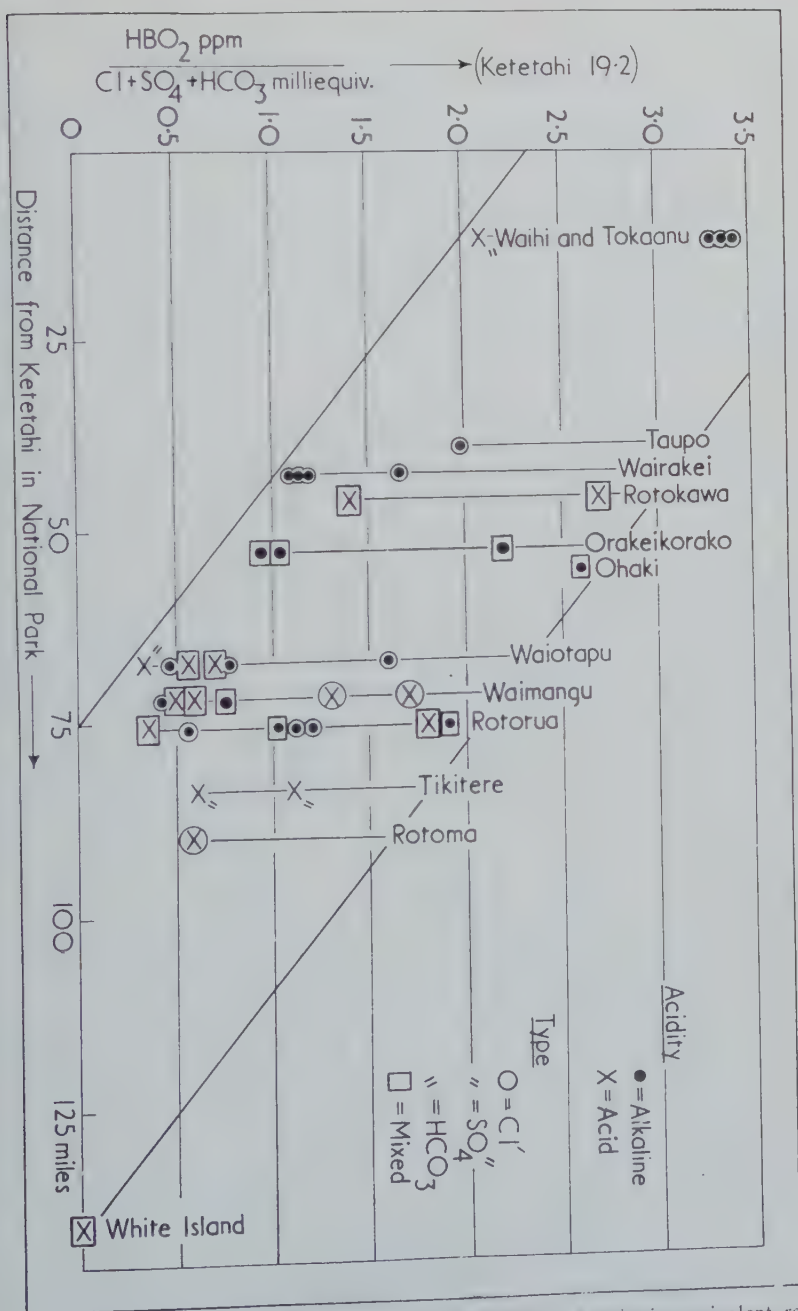


FIG. 3—Graphic illustration of increase in HBO_2 (p.p.m.)/anionic equivalent ratios from White Island towards Tongarirua National Park.

they all contain boron in appreciable amounts, and to infer a magmatic origin for the Hammer waters on account of their boron content is no longer valid. These greywacke rocks are believed to lie beneath the volcanic rocks of the central North Island, so it is not necessarily correct to consider some of the above mentioned radicals as magmatic in origin because they occur as mere traces in the surface volcanic rocks."

A tendency is noted above for boron to be lower in thermal waters the more acidic the associated lavas are. As it is possible, however, that basic magmas lie at greater depths than acidic magmas, steam and hot water from the former would pass through, and leach, greater thicknesses of rock, thereby being relatively enriched in boron (Mr J. Healy, pers. comm.). Thus, although not proved, leaching by rising hot water could be the origin of boron in hydrothermal waters.

CONCLUSIONS

(1) The highest HBO_2 content and HBO_2 /anionic equivalent ratios within ground waters of the Waikato district occur in warm waters which owe most of their heat and salt content to a volcanic origin.

(2) The boron content bears no relation to dominant type of anion or acidity of the Rotorua-Taupo thermal waters.

(3) There is a south-westward increase in boron/anionic equivalent ratios in thermal waters within the dominantly acidic Rotorua-Taupo graben and with change to andesites of Tongariro National Park. The highest boron content and HBO_2 /equivalent ratio is associated with basalts of Ngawha, North Auckland. Thus the increase of boron may be associated with a change from acid to basic volcanism.

(4) Although it has not been proved that the boron content of thermal waters is either derived from a magma, or leached from other deposits, the heat acquired from the magma is probably the dominant factor in mobilising boron.

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REVIEW

GRUNDZÜGE DER ZOOLOGISCHEN MIKROPALÄONTOLOGIE

By VLADIMIR POKORNY. Veb Deutscher Verlag der Wissenschaften, Berlin, 1958. (in German). Vol. 1, 582 pp., 549 figs.; Vol. 2, 453 pp., 527 figs. (Price: Vol. 1, DM 48; 2, DM 35-80).

This ambitious textbook on Micropaleontology written by Professor Vladimir Pokorny of Karls-University, Prague, will attract considerable interest. It is well bound in a rexine cover and printed on thin art paper with illustrations spaced throughout the text, the standard of the printing and reproduction being high.

The first 40 pages are largely taken up with methods of preparation and a short chapter is devoted to "microstratigraphic" practice and correlation. The main part of the book is given over to the classification, biology and stratigraphic use of the following groups of microfossils, a chapter being devoted to each group: Vol. 1, Chapter 4 Radiolaria, 30 pp., Chap. 5 Thecamoebinae, 6 pp., Chap. 6 Foraminifera, 339 pp., Chap. 7 Tintinnina 11 pp., Chap. 8 Incertae sedis including Oligostegina etc., 3 pp., Chap. 9 Chitinozoa, 3 pp., Chap. 10 Hystrichospherids, 14 pp.; Vol. 2, Chapter 11 Porifera 18 pp., Chap. 12 Octocorallia 3 pp., Chap. 13 Scolecodonta 6 pp., Chap. 14 Conodonts 24 pp., Chap. 15 Ostracoda 154 pp., Chap. 16 Echinoderms 28 pp., Chap. 17 Ascidians 1 p., Chap. 18 Otoliths 10 pp.

Ample lists of well classified references are provided and at the end of each volume there is a full index divided into general, taxonomic, and bibliographic sections.

Both Foraminifera and Ostracoda, the two most important groups of microfossils, have been given very full treatment by Professor Pokorny who is widely known particularly as an authority on the latter group. Although Western micropaleontologists will not find any startling changes from the classifications adopted by Glaessner or by Sigal, the continuing instability of the major classification of the Foraminifera is reflected in Professor Pokorny's arrangement of superfamilies: Allogromiidea, Astrorhizidea (9 families), Lituolidea (9 families including Endothyridae), Fusulinidea (2 families), Miliolidea (5 families), Nodosariidea (syn. Lagenidea, 3 families), Buliminidea (4 families), Spirillinidea (1 family, including Patellininae), Rotaliidea (27 families including Discorbiidae and Schackoinidae, new fam.), making a total of 61 families.

This book has obviously been compiled by a worker with a grounding in Northern Hemisphere faunas and Australasian students will be disappointed to find no mention of such important Southern Hemisphere genera as *Notorotalia*, *Siphotextularia*, *Parrellina*, *Virgulopsis*, *Victoriella* or *Hofkerina*, to name a few. Similarly readers inquiring for up to date information on the classification of the Discorbiidae will search in vain for mention of *Discopulvinulina* or *Glabratella*. The chapter on Foraminifera while being a valu-

able source of reference for students cannot be recommended as a *vade mecum* to the professional micropaleontologist. The general lack of full synonymies of genera, which was such a useful feature of Cushman's Classification of the Foraminifera, is unfortunate.

Chapter 15, on the Ostracoda, deals very fully with the structure and classification of Palaeozoic, Mesozoic, and Tertiary groups and is probably the most adequate single account of the ostracods to date. New Zealand readers will be interested to note that the extraordinary Recent species *Manawa tryphena* Hornibrook and *Puncia novozealandica* Hornibrook, discovered off North Cape, are classified under the Paleozoic Order Beyrichiida by Pokorny. The line and stipple drawings which illustrate most of the section on ostracods are clear and unambiguous.

Most English-speaking students will find such a large textbook, written in German, something of a hurdle but the author has minimised the difficulties by providing a glossary of German terms with their English, French, and Russian equivalents.

This book's appeal lies in the numerous references to eastern European and Russian work.

N. de B. HORNIBROOK,
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NEW ZEALAND GEOLOGICAL ABSTRACTS 1957

Compiled by B. W. COLLINS, New Zealand Geological Survey,
Department of Scientific and Industrial Research*

(Received for publication, 30 September 1959)

This is the ninth annual compilation of abstracts of New Zealand geological publications, undertaken by the New Zealand Geological Survey in accordance with the recommendation of the British Commonwealth Specialist Conference on Geology and Mineral Resources in London, in 1948. Previous lists were published in *N.Z. J. Sci. Tech.* (Sec. B) and in vol. 1 of this journal.

The policy of spreading the net fairly widely has been continued, in the belief that the inclusion of marginal references (such as those on soil mineralogy, geophysics, oceanography, etc.) will be found useful both by New Zealand geologists and those overseas. For the same reason papers published overseas that include some significant reference to New Zealand geology and papers published by New Zealand geologists on subjects not strictly confined to New Zealand have also been included.

It should be noted that the length of the abstract given here does not necessarily bear any relation to the length or significance of the original paper. Abstracts of papers in journals less readily available in New Zealand are generally proportionately longer than those of papers in the more accessible periodicals.

For convenience of reference the papers (and other publications) are numbered serially, and have been indexed under the various branches of earth science and also, where possible, under the land districts of New Zealand.

Although no comprehensive attempt can be made here to assess the significance of the publications on New Zealand geology during 1957, it may be helpful to point out that problems of geothermal research (undertaken mainly in connection with the programme of geothermal electric power production) and of Pleistocene and glacial geology have received much attention. Under the first heading papers by Banwell and others (3, 4, 5), Grindley (13 (2)), and Studt (107) are major contributions; and in the second category those by Stevens (104, 105), Suggate (108), and Brodie (10) deserve special mention.

Regional geological bulletins published during the year by the Geological Survey are those by Gage on the Waitaki district (47) and by Suggate on the Reefton district (108). Reed published an important petrological bulletin on the Wellington greywackes (98). Official paleontological bulletins are those by Fleming (41), Marwick (87), and Vella (116).

Book publications of 1957 include that on earthquakes by Eiby (31), and the handbook on science in New Zealand edited by Callaghan (13), which contains a number of articles of geological interest.

Other papers that it may be worthwhile drawing to the attention of overseas readers are:

Bradley on paleogeographic pole (9); Lillie and others on New Zealand alpine structure (81); Cotton on geomorphology and structure (especially 28 and 29); Hornibrook and Harrington on stratigraphy and the status of the Wangaloan Stage (67); papers on structural geology by Kingma (76, 77, 78) and Te Punga (112); and stratigraphic contributions by Kear (72, 73), Mutch (90), and Waterhouse and Bradley (118).

The compiler thanks the following for assistance received: Professor D. S. Coombs, Drs R. N. Brothers, R. A. Couper, C. A. Fleming, M. Gage, H. J. Harrington, W. F. Harris, and J. J. Reed, and Messrs D. R. Gregg, D. Kear, L. E. Oborn, J. C. Schofield, G. C. Shaw, I. G. Speden, R. P. Suggate, and B. N. Thompson; and also to several other authors for copies of their papers.

The authorship of each abstract is indicated by initials or notes in parentheses.

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57/1—ANON: The Coalfields of New Zealand. 4—The Grey. *N.Z. Coal*, 1 (4): 18–21, 24, photos. 5—The Kaitangata Story. *Ibid.*, 2 (1): 2–4, photos. 6—Reefton. *Ibid.*, 2 (2): 18–9, photos.

Continuation of a series of popular descriptive and historical articles, illustrated with numerous new and old photographs. (B.W.C.)

57/2—ANON: Geological Outline. In "New Zealand National Parks", pp. [24, 26], issued by National Parks Authority of New Zealand. Gov. Printer, Wellington. 32 pp. (not numbered), many ill., 9 maps.

Very brief notes on the eight main national parks (three in the North and five in the South Island.) (B.W.C.)

57/3—BANWELL, C. J.: The New Zealand Thermal Area and its Development for Power Production. *Trans. Amer. Soc. Mech. Engrs.* 79 (2): 255–68, 9 figs.

The main thermal area in the North Island of New Zealand is described, and a short account given of its geological history and of its relation to the Pacific seismic and volcanic belt. The prospecting and development drilling programme, commenced at Wairakei in 1950, is presented. Temperature information from the drill holes has been used to prepare several temperature sections through the development area. Wairakei drill holes have nearly all tapped a mixture of steam and water, with a mean enthalpy for all producing holes of 450 Btu/lb. In November 1954, 16 producing holes were discharging a total mass of 1.38 million lb/h, the steam fraction

of which, at 70 lb/sq. in. wellhead pressure, represents a generated power output of 20,000 kw. The total estimated natural heat output of the Wairakei area is equivalent to approximately 100,000 kw of generated power. (Author's abstract.)

- 57/4—BANWELL, C. J.: Flow Sampling and Discharge Measurement in Geothermal Bores. *Trans. Amer. Soc. Mech. Engrs.* 79 (2): 269–78, 16 figs.

The outputs of wells in the thermal area at Wairakei range from 10 million Btu and 20,000 lb per hour to 200 million Btu and 500,000 lb per hour. Wellhead pressures range from about 50 up to 300 psig at these outputs, and the average discharge consists of about 25% steam and 75% water. The development of a sampler for measuring these heat and mass discharges is described. (From author's abstract.)

- 57/5—BANWELL, C. J., COOPER, E. R., THOMPSON, G. E. K., and MCCREE, K. J.: Physics of the New Zealand Thermal Area. *N.Z. Dep. sci. industr. Res. Bull.* 123. 109 pp., numerous figs.

In this Bulletin, certain of the physical characteristics of the phenomena in the thermal area – temperature, enthalpy, heat flow, etc. – are discussed more fully than in the recent "Geothermal Steam for Power in New Zealand". (*D.S.I.R. Bulletin* 117 – see abstract 55/49). An account is also given of some of the experimental methods by which physical data have been collected. Theories of thermal areas in general are reviewed, their possible application to the main New Zealand area considered, and a physical model suggested for the latter as a convenient means for organising existing information and for stimulating further research. (From Introduction.)

The Bulletin consists of a number of independent papers, as follows:

- (1) Banwell, C. J.: Origin and Flow of Heat (pp. 9–37, 3 figs.). Discusses various theories of the nature of the ultimate source of heat responsible for thermal and volcanic phenomena, and of the mode of transfer of this heat to the earth's surface. An attempt is made to show which of these theories best explains the phenomena found in New Zealand. (B.W.C.)

- (2) Banwell, C. J.: Borehole Measurements (pp. 39–71, 19 figs.). Temperatures and outputs of drill-holes, their variation with depth and time, and their relation to natural activity are recorded and discussed. (B.W.C.)

- (3) Cooper, E. R.: Heat Transfer by Conduction and Permeation and the Characteristics of Artificial Bores Placed in the Wairakei Thermal Area (pp. 73–80). Analysis of heat transfer mechanisms, conduction and permeation, the flow of water into a bore, and the steam/water ratio of the discharge are discussed and treated mathematically. (B.W.C.)

- (4) Thompson, G. E. K.: Some Physical Measurements in the Wairakei-Taupo Areas (pp. 81–95, 10 figs.). At Geyser Valley, temperature, mass discharge, pH, chloride content, and electrical conductivity of selected springs were measured. In the Wairora Valley, values of stream temperatures and flow were used as indicators of changes in level of activity. At the Spa Sights on the banks of the Waikato River, the activity of selected springs has been recorded in an attempt to correlate variations with changes in river level. Records of the water table around Wairakei and measurements of earth temperatures have also been made. The section dealing with the Spa Sights was contributed by E. F. Lloyd. (B.W.C.)

- (5) McCree, K. J.: The Great Wairakei Geyser: the State of its Activity in 1951 (pp. 97–104, 5 figs.). Before about 1930 this geyser played once every 10 minutes approximately. The 1951 state of activity was marked by an eruption period varying from about 10 to 23 h. A more regular feature is the occurrence of partial eruptions or "false plays", lasting for less than 1 min compared with the 7 or 8 min of a normal eruption. The first of these "false plays" occurs regularly within 12 h of the previous eruption and there are usually several before the next normal display. (B.W.C.)

- (6) McCree, K. J.: Electrofiltration Potentials in Wells in Geothermal Areas (pp. 105–9, 1 fig.). Experiments have shown that it is possible to locate bands of flow by logging natural potentials; electrofiltration potentials appear when a well is allowed to discharge. The theory of the method and possible future work are discussed. (From author's summary.)

BOREHAM, A. E.: See 57/92.

57/6—BOUCOT, A. J.: A Devonian Brachiopod, *Cyrtinopsis*. Redescribed. *Senckenbergiana Letbaea*, 38 (1-2): 37-48.

C. cooperi Gill (Early Devonian, Australia) is a perlamellosid closely related to North American forms like "*Delthyris*" *perlamellosa* (Hall). Shirley's *Cyrtinopsis perlamellosa* (Hall) from Baton River, New Zealand, is probably a perlamellosid, as suggested by his figures and description. The presence of "concentric lamellae, each of which carries fine radial striations" ban Shirley's material from the genus *Cyrtinopsis*. (C.A.F.)

57/7—BOUCOT, A. J.: Revision of Some Silurian and Early Devonian Spiriferid Genera and Erection of Kozlowskiellinae, New Subfamily. *Senckenbergiana Letbaea*, 38 (5-6): 311-34.

Includes description of *Kozlowskiella* Boucot, n. gen. (Type: *K. strausi* Boucot, n. sp. (= *Delthyris crispata* Muir-Wood, non Linnaeus); Wenlock Limestone, Great Britain), and of its subgenus *Megakozlowskiella* Boucot, n. subgen. (Type: *Spirifer perlamellosus* Hall, 1857) to which is assigned *Cyrtinopsis cooperi* Gill (Lower Devonian, Australia). The genus may be represented in strata of Lower Devonian age in New Zealand by Shirley's "*Cyrtinopsis perlamellosa* (Hall)". (C.A.F.)

57/8—BOUGHEY, A. S.: "The Origin of the African Flora". O.U.P. 48pp. 6 figs.

In this inaugural lecture of the professor of botany in the University College of Rhodesia and Nyasaland there are references to New Zealand on pp. 32, 34, and 45. New Zealand is considered to have remained isolated from the rest of the world since Late Cretaceous times. (B.W.C.)

57/9—BRADLEY, J.: The Meaning of Paleogeographic Pole. *N.Z. J. Sci. Tech. B*, 38 (4): 354-65, 3 figs.

Geomagnetic evidence for "pole wandering" is examined, and the various uses of the term "pole" are defined. It is concluded that geomagnetic evidence on the positions of paleogeographic poles supports the theory of continental drift, rather than the hypothesis of a rigid and moving crust. (Author's abstract.)

BRADLEY, J.: See also 57/118.

57/10—BRODIE, J. W.: Late Pleistocene Beds, Wellington Peninsula. *N.Z. J. Sci. Tech. B*, 38 (6): 623-43, 9 figs.

The lithology and floras of the late Pleistocene beds on Wellington Peninsula and the ^{14}C ages of plant fossils from them indicate a cool period from 20,000 to 23,000 years ago, here named the Takapu Stadial. During this time, gully-fills, the Takapu Beds, were deposited. Weathering and erosion features suggest interstadials following and immediately preceding this phase (Author's abstract.)

57/11—BRODIE, J. W.: Marine Geology of the Chatham Islands Area. In G. A. Knox: *N.Z. Dep. sci. industr. Res. Bull.* 122: 28-30, 2 figs.

All the islands of the Chatham group are enclosed by the 60-m isobath. Shoreward of this line the bottom is irregular with local relief averaging 5 fm. There is a succession of level surfaces at average depths of 52, 32, 21, 16, 10, and 6 fm. The gradient of the outer shelf steepens abruptly landward at an average depth of 65 fm.

Coarse sediments are found mainly shoreward of the 50-fm line, with fine sand seawards to depths as great as 180 fm.

Since the formation of the outer shelf edge the south-western portion has been depressed 15 to 20 fm relative to the eastern portion. This warping took place prior to the cutting of the 65 fm and shallower levels, as also did the "blocking-out by faulting" of the outline of the group suggested by Allan. (See also 57/79.) (B.W.C.)

57/12—BROTHERS, R. N.: The Volcanic Domes at Mayor Island, New Zealand. *Trans. roy. Soc. N.Z.* 84 (3): 549–60, 1 pl., 2 figs.

Three distinct landforms, built during successive periods of volcanic activity, are named the main cone, the old dome, and the young dome. The upper part of the main cone was removed during the formation of the main crater that now occupies the centre of the island. The main crater floor was covered by lavas of the old dome. This structure was later largely destroyed when a fault with north-east trend intersected the vent and initiated violent pumice eruptions. The greater part of the old dome collapsed into the vent, and the caldera so formed was occupied by a series of lava flows belonging to the young dome. (Author's abstract slightly modified.)

57/13—CALLAGHAN, F. R. (ed.): "Science in New Zealand". Reed, Dunedin. 272 pp. frontispiece, 37 pls., numerous figs.

This handbook prepared for the 32nd meeting of the Australian and New Zealand Association for the Advancement of Science, held in Dunedin, January 1957, contains, among others, the following articles of interest to geologists:

(1) Geophysics, by E. I. Robertson (pp. 36–45). A brief survey of the organisation of geophysical research in New Zealand, with reference to recent work, under the following headings: meteorology, oceanography, seismology, geomagnetism, cosmic rays, physics of the upper atmosphere (ionosphere, aurorae, radio propagation), geophysical prospecting, and geodesy (geodetic surveys, gravity). (B.W.C.)

(2) Geothermal Power, by G. W. Grindley (pp. 112–22, 2 pls. 2 figs.). Discusses the structure and deposits of the volcanic zone of New Zealand; recent volcanic and tectonic activity; the history and methods of scientific investigation; the location, drilling, and testing of steam wells; and the origin of the steam. Present information suggests that Quaternary ignimbrite overlies sediments and breccias that in turn overlie Mesozoic greywacke. The sediments are compacted and probably impermeable, and large steam traps are not to be expected in them. Flow of steam and superheated water is probably confined to a few major fissures, and the location of these by drilling is likely to be difficult. Future prospects lies in deeper drilling on the fissures at Wairakei and in exploitation of the resources of other thermal areas. (Mainly from author's conclusion.)

(3) The History of Soil Science, by I. J. Pohlen (pp. 153–63, map). The New Zealand Soil Bureau started about 1930 as a branch of the Geological Survey, but now covers many other branches of soil science besides pedology. The article contains a map, prepared in 1954, of the soil-forming volcanic ash showers of the North Island. (B.W.C.)

(4) Trans-Tasman Relationships in Natural History, by C. A. Fleming (pp. 228–46, 1 pl. 6 figs.). New Zealand and Australia gained a nucleus of their terrestrial littoral plants and animals by land in the Upper Cretaceous either from Asia or possibly by a southern route. New Zealand became isolated from other lands before the spread of mammals and has not subsequently been connected with other land masses, but land may have extended north-westward during the Tertiary. The older elements have evolved and become differentiated independently on either side of the Tasman during the Tertiary. Many organisms of diverse groups have been able to cross the seas and colonise New Zealand at intervals during the Tertiary, coming from the north (Indo-Pacific), from Australia, and from the subantarctic, to form the newer but less distinctive elements, which are numerically strong in both fauna and flora.

The article discusses the evidence of marine and land fossils and of living organisms, and with the aid of paleogeographic maps of the Australasian region considers geographical changes and the question of land bridges during geological time. (Author's summary extended.)

(5) Post-War Oceanography, by R. M. Cassie (pp. 262–72, 1 pl. map). Concerned mainly with marine biology and aspects of physical oceanography other than submarine geology, but includes a bathymetric chart of the New Zealand area. (B.W.C.)

CASSIE, R. M.: See 57/13 (5).

- 57/14—CASTER, K. E.; GILL, E. D. Australian and New Zealand Devonian and Silurian Carpoids (Abstract). *Bull. Geol. Soc. Amer.* 68 (12, pt 2): 1707.

Two new mitrate (placostylid) carpoids recently obtained from the Silurian of Victoria and the Reefton Devonian of New Zealand appear to be unrelated to Brazilian and South African forms, but show European and North American affinities. (B.W.C.)

CHITTENDEN, E.: See 57/102.

CHRISTIE, J. M.: See 57/84.

- 57/15—CHUBB, L. J.: The Pattern of Some Pacific Island Chains. *Geol. Mag.*, 94 (3): 221-8.

Contains brief references to the Samoa and Cook island groups, especially in regard to the progressive movement of volcanicity along the island chain, and to tilting in the case of the Cook group. (B.W.C.)

CLARIDGE, G. C.: See 57/99.

- 57/16—CLARK, R. H. Ophitic Texture and Basaltic Crystallization. (Note.) *J. Geol.* 65 (5): 558.

Points out that Clark's (1952) statement on the origin of ophitic texture quoted by F. Walker (*J. Geol.*, 65, 1957) referred only to the rocks discussed in Clark's 1952 paper - the microporphyritic ophitic basalts of Arthur's Seat, Scotland. (B.W.C.)

- 57/17—COLLINS, B. W. (compiler): Abstracts of Papers on New Zealand Geology. Published in 1955. *N.Z.J. Sci. Tech.* B38 (8): 903-24.

Abstracts of 112 papers and other publications, with subject and regional indexes.

- 57/18—COLLINS, B. W.: Water Divining - Old and New. *N.Z. Sci. Rev.* 15 (3-4): 19-26.

The uniqueness of water as a mineral and the water regime of the earth are discussed, especially with regard to past glaciations. The long history of water divining is summarised, and the opinions of others (including geologists and well drillers) are quoted. Tests of diviners conducted by the author and others are described and their failure to substantiate their claims emphasised. Finally brief reference is made to modern methods of studying and locating ground water. (B.W.C.)

- 57/19—COOMBS, D. S.: "The Growth of the Geological Sciences". Univ. of Otago, Dunedin. 19 pp.

In this inaugural lecture the value of geology as a pure and applied science is discussed, and then the history of the development of the science is described, with special emphasis on the quantitative and experimental approach. The author claims that "for a fuller understanding of the earth, we must experiment as well as observe". Modern advances in mineralogy, and historical and physical geology referred to, include X-ray crystallography, radio-carbon dating, geophysical techniques, and paleomagnetism. An increasingly profitable application of physical and experimental methods is predicted for the future. (B.W.C.)

- 57/20—COOMBS, D. S.: Prof. W. N. Benson, F.R.S. (Obituary). *Nature*, 180 (4594): 1023-4.

Brief biographical details of the late professor of geology at Otago University (1916-1949), the doyen of New Zealand geologists. His main researches included a classic study of the Great Serpentine Belt of New South Wales, the Ordovician rocks of New Zealand, and the late Cainozoic petrographic province of East Otago. His publications total well over a hundred. (B.W.C.)

COOMBS, D. S.: See also 57/50.

COOPER, E. R.: See 57/5.

- 57/21—COTTON, C. A.: Tectonic Features in a Coastal Setting at Wellington. *Trans. roy. Soc. N.Z.* 84 (4): 761–90, 6 pls, 10 figs.

In addition to major relief related in origin to the transcurrent Wellington Fault and the Port Nicholson and Porirua Harbour tectonic basins, a pattern of smaller tectonic blocks and related forms is recognised. The shapes and outlines of these blocks largely control the pattern of drainage, which must therefore be described as mainly consequent.

The tectonic pattern is made evident by the partial preservation of a "key" land surface or terminal peneplain. This surface, now called the K surface, was probably developed by the erosion that followed, rather than by that which preceded, the Tertiary orogenic disturbance known as the Kaikoura Orogeny.

Early-formed blocks and arched surfaces produced by deformation of the K surface are now considerably dissected. Intermittent earth movement, especially on or closely parallel to the Wellington Fault, has continued until very recently, and must indeed be considered active still. Port Nicholson and Palliser Bay are the major features of the south Wellington coast of transverse deformation, and they are possibly secondary effects of transcurrent drift along the Wellington Fault. (Author's abstract abridged.)

- 57/22—COTTON, C. A.: Pleistocene Shorelines on the Compound coast of Otago. *N.Z. J. Sci. Tech. B*, 38 (7): 750–62, 4 figs.

The eastern Otago and North Auckland coasts are the only ones in New Zealand sufficiently unaffected by Pleistocene differential movements to yield a possibly reliable record of ice-age oscillations of ocean level and of the unexplained progressive withdrawal of the ocean to lower levels in Pleistocene times.

The eastern Otago coast is a normal one in that small estuaries and drowned valleys testify to the Flandrian return of the ocean after its withdrawal during the last glaciation. Yet here these are only minor features; the coastal form is compound, with both its primitive outline and terraces developed on it by marine erosion surviving from earlier times.

Of the two principal terraces cut on resistant rocks the higher is too high to be Tyrrhenian unless there has been some sensibly uniform upheaval of the coast. Admission of progressive upheaval would reduce the value of measurements of terrace heights for purposes of world-wide correlation. (Author's abstract abridged.)

- 57/23—COTTON, C. A.: An Example of Transcurrent-Drift Tectonics. *N.Z. J. Sci. Tech. B*, 38 (9): 939–42, 2 figs.

Drift along the New Zealand transcurrent-fault zone where it borders the axial range of the North Island has probably caused an accumulation of stress which has been relieved by upthrust of the Mt. Miriroa block in central Hawke's Bay. In an analogous case in California, accumulated stress attributed to transcurrent drift is relieved by activity of the White Wolf Fault, causing earthquakes. (Author's abstract.)

- 57/24—COTTON, C. A.: The Pukerua Tectonic Corridor, Wellington. *N.Z. Geogr.* 13 (2): 117–24, 6 figs.

The flat-floored Pukerua tectonic corridor branches from a chain of down-warped basins in the Wellington district and extends northward from the Porirua Harbour basin to the shore of Cook Strait at Pukerua Bay. Examples of tectonic and erosional landform development in the vicinity are described. These include what may be a pediment to the west and a tilted block to the east. The eastern block is traversed by a narrow furrow on the line of the Kahao Fault and is partly crossed by antecedent gorges. (B.W.C.)

- 57/25—COTTON, C. A.: Volumes of Ice Sheets, Past, Present, and Future. (Review.) *N.Z. Sci. Rev.* 15 (5–6): 40.

A review of a paper by A. Cailleux (*Bull. Soc. Geol. France*, 6 (4): 243–53, 1954). Melting of all present ice would raise the sea level by 125 to 215 ft. The maximum lowering during the Pleistocene was 300 to 500 ft. The hypothesis of subaerial erosion of submarine canyons is rehabilitated; panglacierisation of the earth (possibly during the Precambrian) would lower sea-level by 9,000 ft. (B.W.C.)

- 57/26—COTTON, C. A.: A Slow Tempo of Denudation Claimed for Eastern Australia. (Letter to Editor.) *Geol. Mag.* 94 (4): 341-2.

Casts doubt on the suggestion of Noakes (1954) that the Canberra region has undergone very little erosion since Paleozoic times. (B.W.C.)

- 57/27—COTTON, C. A.: Criteria for the Classification of Coasts. *Proc. 17th Int. Geogr. Congr. (Washington, 1952)*: 315-9.

The classification of coasts according to the structure of their hinterland into "Atlantic" and "Pacific" types is unsatisfactory. Also, because of oscillation of ocean level, nearly all coasts must be compound (in Johnson's sense) rather than "submerged" or "emerged". It is suggested that coasts should first be divided into those of stable regions (all drowned in the recent Flandrian submergence, but in reality compound), and those of mobile regions (all compound, but affected by diastrophic as well as eustatic changes of sea-level). Each of these classes may be further subdivided into those with features dominated by (a) submergence, (b) emergence. A third category of mobile region coasts includes "coasts of transverse deformation". This classification applies only to the initial forms of coasts. Subsequently the initial forms may be eroded or prograded. (B.W.C.) (Publication date not given.)

- 57/28—COTTON, C. A.: Geomorphic Contrasts in Central New Zealand. *Tijdsch. Kon. Nederl. Aardrijksk. Gen.* 74 (3): 248-53, 2 pls. 3 figs.

Four districts in central New Zealand (adjacent to Cook Strait), one surrounding the city of Wellington, in the North Island, but the other three in the South Island, present strikingly different topographic expressions. Two of the South Island districts, the Kaikoura Ranges and northern Nelson, conform to the New Zealand type of landscape characterised by broad tectonic valleys separating ranges that were upheaved in a late Tertiary orogeny, though these two are not alike in that a resurrected peneplain survives conspicuously as high plateaux in the latter but not at all in the former. The other two present entirely different physiognomies. The Wellington district, less mountainous than any of the others, as though late Tertiary tectonic relief, if ever strong, had been destroyed by erosion, now displays instead a minor tectonic relief produced apparently by more recent diastrophism. Still more different is the Marlborough Sounds district, for it is dissected to full maturity, with an apparently insequent (though possibly consequent) pattern of valleys, retaining, however, strong relief, though it has been depressed and deeply drowned, so that rias penetrate far inland, reducing the land to a skeleton of branching promontories. An attempt is made to reconcile these differences with the Quaternary history of the region, and to present the setting of the Wellington landscape in particular in the New Zealand regional scheme. (Author's abstract.)

- 57/29—COTTON, C. A.: Geomorphic Evidence and Major Structures Associated with Transcurrent Faults in New Zealand. *Rev. Geogr. Phys. Geol. Dyn. ser. 2*, 1 (1): 16-30, 3 pls., 14 figs.

Great transcurrent faults have been recognised in New Zealand. For the north-east-trending Alpine Fault 500 km of lateral displacement throughout Cretaceous and later times has been claimed. A sheaf of other faults which have very recently been affected by similar dextral transcurrent movement branch east-north-east from the Alpine Fault. Recent horizontal movement of varying amount up to 1 km is indicated by the offsetting of stream courses, and there is also some other corroborative geomorphic evidence; but features so produced are ephemeral.

The New Zealand region has been strongly affected by Pliocene and again by rather late Pleistocene orogenies; but these were separated perhaps throughout the region — and certainly in the southern part of the North Island — by a long anorogenic interval. The Pleistocene orogeny did not affect the whole New Zealand region; it was most pronounced in the southern part of the North Island.

The hypothesis has been proposed that buckling such as may accompany transcurrent faulting — notably such drift along the branch faults, of which one, the Wellington Fault, passes through the city of Wellington — has been the cause of the later (localised) orogeny and especially of the tectonic relief at Wellington. The earlier and more

widespread mountain-making deformation may have resulted from drift along the main transcurrent-fault zone, which, it has been suggested, follows the surface trace of a geosuture in the subcrustal material of the earth. (Author's abstract.)

COUPER, R. A.: See 57/47 and 57/108.

57/30—CUTLER, E. J. B.: Soils of the Lower Clutha Plains. *N.Z. Soil Bur. Bull.* 15. 40 pp. 13 figs. 1 map.

The geology of the Lower Clutha Plains is summarised under the heading of "Physiography". Terraces, sand dunes, flood plains and peat bogs are discussed briefly (pp. 6, 10) and their distribution has been mapped (Fig. 2). (D.K.)

DIBBLE, R. R.: See 57/32.

DUFF, R.: See 57/50.

57/31—EIBY, G. A.: "Earthquakes". Muller, London. 168 pp. 32 pls. 54 figs.

A popular exposition of where and why earthquakes occur, how they are recorded, and the interpretation of seismograph records. The evidence of seismology on the internal constitution of the earth is discussed and the seismic method of geophysical prospecting. The use of microseisms to provide hurricane warnings, the relation of volcanoes and seismic sea waves, modern views on earthquake-resistant buildings, and a number of great earthquakes both in New Zealand and overseas are also referred to. In regard to the possible prediction of earthquakes the author states that in any case its utility is open to question. "It is probably wiser to turn our ingenuity and our labours to framing sound building codes and devising better methods of construction." (p. 108.) (B.W.C.)

57/32—EIBY, G. A., DIBBLE, R. R.: Crustal Structure Project. *N.Z. Dep. sci. industr. Res. Geophys. Mem.* 5. 40 pp. 2 pls. 9 figs.

This memoir consists of the following parts:

(1) The Wellington Profile, by G. A. Eiby (pp. 6–31, 2 pls. 8 figs.). Interpretation of a seismic refraction profile recorded in the Wellington district shows that the crust has a total average thickness of slightly more than 18 km down to the Mohorovicic discontinuity in this region. It probably consists of four layers with thicknesses of 0.6₁, 1.6₆, 7.1₆, and 8.8 km, in which the velocities of longitudinal waves are 3.5, 5.5₂, 6.0₇, and 6.2₂ km/sec respectively. Below it a velocity of 8.0₂ km/sec was observed. An attempt is made to describe this structure in geological terms.

(2) The Seismic Energy and Magnitude of the Explosions, by R. R. Dibble (pp. 32–35). Includes observations of the amplitude of ground movement close to the shot-point.

(3) The Pencarrow Profile, by G. A. Eiby (pp. 36–9, 1 fig.). A second profile, also near Wellington, shows a smooth increase in velocity from about 3.5 km/sec at the surface to 5.5 km/sec, at a depth of 1 km. It is concluded that velocities less than 5.5 km/sec, met in natural earthquake studies, should be assigned to more recent sediments and not to basement greywacke.

(4) Appendix: Note on the Velocity Discontinuity at a depth of 2 km in the Wellington Region, by G. A. Eiby (p. 40). Concludes that a change in water content will not provide a satisfactory explanation of the discontinuity as had been suggested by geologists. (Mainly from authors' abstracts.)

57/33—ELLIS, A. J.: Chemical Equilibrium in Magmatic Gases. *Amer. J. Sci.*, 255 (6): 416–31, 3 graphs.

From standard thermodynamic data the theoretical compositions of some water, sulphur, carbon dioxide gas systems are calculated for a wide range of temperatures and pressures. It is concluded that a high pressure and temperature solution of CO₂ and H₂S existing at depth in equilibrium with carbonates and sulphides in the parent lava could, on release of pressure, give rise to the common constituents found in magmatic gases at the surface. The fact that the presence of other constituents such as

HCl, NH₃, CH₄, and COS in natural magmatic steam can also be predicted for any temperature from theory, is further evidence that magmatic gases closely approach a state of equilibrium. Data on natural gases from White Island are included. (From author's abstract.)

- 57/34—EVISON, F. E.: The Pulsed Vibrator as a Seismic Source. *Geophys. Prospecting*, 5 (4): 381-91.

Non-explosive seismic sources, notably the falling weight and eccentric machine, have occasionally proved advantageous in experimental and practical seismology in spite of their relative feebleness. Another alternative is the pulsed vibrator, which offers the advantage of a completely controllable waveform. Recent theory shows that such a source is quite well adapted to the radiation of high frequency waves from the surface of the ground; it is estimated, for example, that in typical circumstances reflections should be obtainable from depths of the order of 200 m. (From author's abstract.)

FALLA, R. A.: See 57/50.

- 57/35—FERGUSON, G. J.; RAFTER, T. A.: New Zealand ¹⁴C Age Measurements. 3. *N.Z. J. Sci. Tech., B*, 38 (7): 732-9.

This paper gives details in tabular form of 60 samples dated in the Dominion Physical Laboratory by the radiocarbon method in the period from May 1955 to May 1956. No basic changes in the method used have been made. The way in which errors are assigned to the dates given is described. Twenty-two of the samples were from the North Island, 24 from the South Island, and the remainder from Australia (9), Syria (3), and India (2). Many are of geological interest. (B.W.C.)

- 57/36—FIELDER, M.: Clay Mineralogy of New Zealand Soils. 4—Differential Thermal Analysis. *N.Z. J. Sci. Tech., B*, 38 (6): 533-70, 9 figs.

Differential thermal patterns of fifty-two soil clays are presented. Soils represented are typical of various classes of Taylor's genetic classification of New Zealand soils. Twenty constituents of soil clays are identified. The differential thermal method gives evidence of varying degrees of order in structures of colloids of the allophane-kaolin series; in conjunction with X-ray data, it distinguishes between the forms of crystalline silica of primary and secondary origin (quartz and chalcedony), and it provides information concerning the nature of forms of hydrous alumina and iron oxide that are amorphous to X-rays. (From author's abstract.)

- 57/37—FIRTH, C. W.: The Auckland Water Supply System. *N.Z. Engng.* 12 (9): 292-306, 3 figs. 1 photo.

Includes brief references to geology (pp. 292, 295), and ground water (Western Springs, p. 294). (B.W.C.)

- 57/38—FLEMING, C. A.: A New Devonian Lamellibranch from Reefton, New Zealand. (Note.) *Trans. roy. Soc. N.Z.* 84 (4): 943.

A preliminary description of a new genus and species, *Paleodora reeftonensis* (Solenomorphidae?), from the Reefton Mudstone (Coblenzian, Lower Devonian) of Rainy Creek and Lankey Creek. (B.W.C.)

- 57/39—FLEMING, C. A.: Lower Devonian Pelecypoda from Reefton, New Zealand. *Trans. roy. Soc. N.Z.* 85 (1): 135-40, 2 pls. 4 figs.

Actinopteria mackayi n. sp. is described from the Reefton Mudstone of Lankey Creek. *Pterinopecten* (*Pseudainiculopecten*) *casterorum* n. sp. from the same formation in Rainy Creek is the first member of the Pterinopectinidae to be recorded from New Zealand. *Paleodora* Fleming, a distinctive genus provisionally classed in the Solenomorphidae, is described in detail, and its sole species *P. reeftonensis* Fleming, from the Reefton Mudstone of Lankey and Rainy Creeks, is figured for the first time. (Author's abstract.)

- 57/40—FLEMING, C. A.: The Ages of Some Quaternary Sediments from Wanganui District (N 137, N 138). *N.Z. J. Sci. Tech. B*, 38 (7): 726–31, 1 fig.

The sequence and correlation of late Pleistocene-Holocene formations in Wanganui district are discussed in the light of four radiocarbon dates. The coastal plain formations of the Hawera Series in its type area are older than 45,000 years and thus older than the later substages of the Last Glaciation. An important shower of pumice lapilli was erupted into the headwaters of the Wanganui River about 250 B.C. A forest at Waitotara River has subsided several feet in the past thousand years. (Author's abstract.)

- 57/41—FLEMING, C. A.: The Genus *Pecten* in New Zealand. *N.Z. Geol. Surv. Pal. Bull.* 26. 69 pp. 15 pls. 13 figs.

The morphology, biology, geographic and stratigraphic distribution, and dispersal ability of scallops belonging to the genus *Pecten* (s. str.) are discussed as a basis for their classification. Australasian forms of *Pecten* were apparently derived from a few parental stocks which developed in the Mediterranean and spread eastward to the Pacific during the Pliocene and Pleistocene. New Zealand fossil and living forms are systematically described and classified in two species-groups and four polytypic species to show their relationship with those of other parts of the Old World. Two new subspecies, *P. benedictus tepungai* and *P. b. zeebaenae*, are described.

During the Pleistocene, the boundary between the distribution areas of the two species-groups of *Pecten* fluctuated across New Zealand, probably owing to climatic changes, so that distinct fossil scallops are preserved in sequence in the Castlecliffian Stage (Pleistocene) of the Wanganui Basin and can be used as zonal indices. Outliers of Castlecliffian in other parts of the North Island are correlated with the zones of the type Castlecliffian from the fossil pectens they contain. (Author's abstract.)

- 57/42—FLEMING, C. A.: A New Species of Fossil *Chlamys* from the Drygalski Agglomerate of Heard Island, Indian Ocean. *J. Geol. Soc. Aust.* 4 (1): 13–9, 1 pl. 1 fig.

Chlamys (*Zygochlamys*) *heardensis* n. sp. is described from specimens collected from the Drygalski Agglomerate of Heard Island. Its relationships with other large forms of Subantarctic *Chlamys*, fossil and living (including New Zealand forms), indicate that the agglomerate is Neogene in age, probably post-Miocene and perhaps Pliocene. (Author's abstract slightly modified.)

- 57/43—FLEMING, C. A.: The Triassic Lamellibranch *Torastarte bensoni* Marwick. *Proc. Malacol. Soc. Lond.* 32 (4): 173–5, 1 pl.

North Island specimens of *Torastarte bensoni* Marwick, described from the Otagian Stage (Rhaetian) of Southland, confirm the conclusion of K. Ichikawa that *Torastarte* is a member of the Cardiniidae, differing from *Cardinia* (chiefly Liassic) in its rounder, less elongate outline, in its coarse regular concentric sculpture, and in its gerontically ingrown escutcheon and nymph. (C.A.F.)

- 57/44—FLEMING, C. A.: On the Supposed Occurrence of *Tanea zelandica* Quoy and Gaimard (Naticidae) in New Caledonia. *J. Conchylol.*, 97: 141–2.

Concludes that there is no evidence for the presence of this shell in New Caledonia. In fact the genus *Tanea* (related to *Natica*), which has been present in New Zealand since the middle Tertiary, appears to be endemic. (B.W.C.)

FLEMING, C. A.: See also 57/13 (4), 57/14, 57/92, and 57/108.

- 57/45—FLEMING, C. A.; HORNIBROOK, N. de B.: Support for Dr W. J. Arkell's Proposal for the Withdrawal of Copenhagen Decision 54 (1) (a). *Bull. Zool. Nomenclat.* 15 (5–6): 137.

A brief, formal affirmation of the authors' belief that the name of a family, subfamily, and superfamily should be based on the valid name of the type genus. (B.W.C.)

FOWLDS, G. M.: See 57/52.

57/46—FYFE, W. S.: A Chemist Looks at Geology. *J. N.Z. Inst. Chem.* 21 (2): 34-43, 7 figs.

An address on geochemistry and experimental geology using chemical and physical methods, referring especially to the crystallisation of igneous rocks and reactions at high temperatures and pressures. Otago University is setting up a laboratory to undertake this type of work. (B.W.C.)

57/47—GAGL, M.: The Geology of Waitaki Subdivision. *N.Z. geol. Surv. Bull.* 55. 135 pp. 33 figs. 3 geol. maps, 1 sheet sects.

The geology of an area of approximately 600 square miles in the Otago district is described in detail. Long regarded as one of the classic areas of New Zealand Tertiary geology, the area contains the Pre-Cretaceous Kakanui Metamorphic Group of low-rank schist and phyllite; 14 Upper Cretaceous and Tertiary formations assigned to 7 groups; and Quaternary deposits comprising older and younger terrace gravels, recent flood plain deposits, raised shoreline deposits, and loess. The distribution of these formations is shown on maps to the scale of 1 in. to the mile, and their structure on 4 sections to the same horizontal scale but with a vertical scale of 1 in. to 2,000 ft.

The area includes the following topographic features:

- (1) The north-east flank of the Kakanui Mountains (up to 4,200 ft) of metamorphic rocks.
- (2) Rolling downland and mesa-and-cuesta topography sculptured from gently-deformed Cretaceous and Tertiary sediments and volcanic rocks.
- (3) An extensive sloping tableland capped by gravel and loess.
- (4) Gravel-capped river terraces.
- (5) The alluvial plains of the Waitaki and Kakanui Rivers and a narrow coastal plain north of the town of Oamaru.

The main interest and importance of the area lies in its Upper Cretaceous and Tertiary stratigraphy. It had previously been recognised that lithological boundaries were inclined to time planes at Oamaru, but the situation is even more complicated than this. Repeated slight fluctuations of base level during the Eocene and Oligocene produced a mesh of interlinking "phases" and concealed erosion breaks that is difficult to unravel. The Cretaceous and Tertiary beds appear to be deposits from epeiric seas flooding a relatively stable platform outside the main Tertiary mobile belt of the New Zealand area. During a given interval of time far less sediment accumulated here than in the geosynclinal areas of the North Island east coast and Southland. At Oamaru, therefore, a local uplift of the order of a few feet, such as would leave little trace in a geosynclinal section, could result in the planing away of the deposits of an entire stage.

Rather than add to the existing confusion by further attempts to redefine old stratigraphic terms, the writer has abandoned several traditional Oamaru names and set up a new strictly local classification, based mainly on lithogenetic units.

After an introductory section, the geomorphology and geological history of the region are discussed, and then the formations present are described in detail (pp. 19-64). A short chapter on structure (pp. 65-8) is followed by a section on economic deposits (pp. 69-76). The latter include coal, alluvial gold, quartz sands, slate, limestone, building stone, and clay.

There are the following appendices:

- (1) Columnar sections (of the sequences exposed at some 25 important localities);
- (2) Plant Microfossils from the Papakaio Formation, by R. A. Couper (p. 103);
- (3) Brachiopod Faunas, by R. S. Allan (pp. 104-7). Lists species collected and identified by Allan from 8 formations, with notes on their age;
- (4) Fossil Mollusca, by O. P. Olson (pp. 108-27), with an introductory note by C. A. Fleming. Consists of tables of identifications of the abundant fossils from 9 formations, including earlier collections. (B.W.C.)

57/48—GAGE, M.: New Zealand. In "Report of the A.N.Z.A.A.S. Committee for the Investigation of Quaternary Strandline Changes". *Aust. J. Sci.*, 20 (1): 5-6.

Extension of the scope of the Committee's investigations to include tectonic effects removes a severe restriction as far as New Zealand is concerned and permits reference to work on the less stable areas making up a great part of New Zealand. Seven recent papers are reviewed. (B.W.C.)

GILL, E. D.: See 57/14.

57/49—GLAESSNER, M. F.: Cretaceous Belemnites from Australia, New Zealand, and New Guinea. *Aust. J. Sci.* 20 (3): 88-9.

Re-examination of specimens has shown that the grooves that are the main distinguishing feature of *Dimetobelus* Whitehouse are ventro-lateral and not dorso-lateral as hitherto described. Both *Belemnites superstes* Hector and *B. lindseyi* Hector (type of *Cheirobelus* Whitehouse) correspond closely with Australian and New Guinea *Dimetobelus* and their grooves are ventro-lateral (as described by Woods) and not dorso-lateral (as interpreted by Whitehouse). *Cheirobelus* cannot be distinguished generically from *Dimetobelus*. The two ventro-lateral furrows of all *Dimetobelidae* form the most distinctive character of this family; its relationships with *Belemnopsidae* and *Belemnitellidae* are discussed. (C.A.F.)

57/50—GOLSON, J.: New Zealand Archaeology, 1957. *J. polynes. Soc.* 66 (3): 271-90.

A report of the second annual conference of the New Zealand Archaeological Association, held at Dunedin, May 21-23, 1957. Includes summaries of the following contributions of some interest to geologists:

The Habits, Distribution, and Ecology of the Moa and Contemporary Bird Fauna, by R. A. Falla;

Some Thoughts on the Extinction of the Moa, by C. A. Fleming;

Post-Pleistocene Climates: The Forest Record, by J. T. Holloway;

The Moa-swamp at Pyramid Valley, by R. Duff;

The Use of Petrology in Delimiting the Sources of the Stone Materials of the Moa hunters, by D. S. Coombs;

Obsidian Artefacts, Pre-Maori and Maori, by W. J. Phillipps; and

Sites of Moahunter Affiliations in the Wellington District and their Geological Correlations, by G. L. Adkin. (B.W.C.)

57/51—GOLSON, J.: The Contribution of the Natural Sciences to Archaeological Research. *N.Z. Sci. Rev.* 15 (7-8): 56-60

A considerable body of evidence now exists in both the South Island and the North Island for associating the earliest period of New Zealand settlement (the moahunter stage) with the innermost belts of sand dunes. There is also some evidence of the latest phases of volcanic activity in central districts of the North Island overlapping the earliest phase of human settlement in the Bay of Plenty region. Differences in the molluscan species represented in successive midden groups reflect either changes in distribution or differences of food habits on the part of successive groups of people. There is an extensive bibliography. (W.F.H.)

57/52—GOLSON, J. (editor): "Auckland's Volcanic Cones: A Report on Their Condition and a Plea for Their Preservation". With an Appendix by G. M. Fowlds: "Auckland's Volcanic Cones and Craters (Tabular Survey)". Historic Auckland Society, Auckland. 32 pp., 5 photos, map.

An account of the basalt cones, craters, etc., of the Auckland Isthmus, of the effects of past quarrying, and of prospects for the future, and recommendations for preserving those that are left. (C.A.F.)

57/53—GRADWELL, M. W.: Patterned Ground at a High-Country Station. *N.Z. J. Sci. Tech.* B. 38 (8): 793-806, 5 figs.

On gentle slopes at Molesworth Station, Marlborough, bare expanses of subsoil commonly 50 ft or more in diameter are composed mainly of fine soil on which massive needle ice has been observed in winter. On many of these areas are found stone

stripes, typically 5-10 in. apart, and where the slope is very slight there are found instead stone nets 5-10 in. in diameter. Structures transitional between these types are also seen.

In some places, where no stones are present on the soil surface, networks of shrinkage cracks form. These persist throughout the year, and in winter the growth of needle ice is concentrated under the polygonal centres.

The rates of movement of painted stones 1-3 in. in diameter placed on these patterns were recorded. Stones moved downhill at average rates of 1-5 in. a year on slopes of from 2°-5° and of 6-9 in. a year on slopes of about 10°. Three-tenths of the stones placed on the fine-earth centres between stone stripes moved into the stone stripes in two years. Half of the stones placed in the centres of shrinkage-crack nets had lodged in the cracks in two years. No stones were raised to the surface by frost from a depth of 1 in. in that period. (From author's abstract.)

57/54—GRANT-TAYLOR, T. L.: Ground Water in the Poverty Bay Flats. *N.Z. J. Sci. Tech. B*, 38 (7): 763-72, 3 maps.

There are three main groups of water-yielding sediments in the Poverty Bay Flats. All of these will yield water in sufficient quantity for domestic and general agricultural purposes. Only two will deliver water of appropriate quality and in sufficient quantity for irrigation. These are the beach sands, 0-25 ft, and the shallow gravels 15-100 ft below the surface. The gravels deeper than 100 ft would deliver water sufficient in quantity, but this water is corrosive. For industrial purposes within the borough of Gisborne, the beach sands give an adequate supply of water. Brief logs of selected wells are given in an appendix. (Author's abstract modified.)

57/55—GREGG, D. R.: Eruption of Ngauruhoe, January 1956. *N.Z. J. Sci. Tech. B*, 38 (7): 683-5, 1 fig.

The andesite volcano Ngauruhoe erupted in January 1956. Ash was discharged from 13 to 22 January. The ash emission was preceded by greatly increased steam discharge. (Author's abstract.)

57/56—GREGG, D. R.: The Tectonic Setting of the Tongariro Volcanoes, New Zealand. *Abstr. 9th Pacif. Sci. Congr.*: 121.

Active faulting takes place along the central volcanic belt of the North Island, which is aligned with the Tonga-Kermadec Ridge. Earthquake epicentres are generally of intermediate depth (70-300 km). The structure is a simple graben with Mesozoic basement rocks, overlain in places by pre-volcanic late Tertiary marine sediments. (B.W.C.)

57/57—GRINDLEY, G. W.: Mesozoic Orogenies in New Zealand. *Abstr. 9th Pacif. Sci. Congr.*: 116.

The New Zealand geosyncline, extending east and north of the present coastline, was a major tectonic feature in the late Paleozoic and early Mesozoic. In the Permian and Triassic, active volcanoes on the geanticlinal ridge to the west and south supplied volcanic detritus to the sediments on the subsiding flanks of the geanticline. The ridge itself rose rapidly through the Triassic and a wedge of coarse sediment (Hokonui facies) was built out towards the geosyncline.

Folding and elevation of the sediments occurred in the Jurassic, as indicated by shallow-water and carbonaceous sediments in two belts flanking the axis of elevation (schist anticline). The metamorphic core (schist axis) of the geosyncline was exposed in the early Cretaceous in Otago, but the eastern belt continued to subside and the axis migrated eastwards. In the late Cretaceous only a small area in the extreme north-east of New Zealand was truly geosynclinal. Volcanism in the late Mesozoic included spilitic pillow lavas and dolerites, and a line of andesitic volcanoes on the Pacific side of the East Coast geosyncline.

Large (300-mile) post-Triassic clockwise transcurrent displacement on the Alpine Fault complicates compilation of the paleogeographic maps. (B.W.C.)

GRINDLEY, G. W.: See also 57/13 (2).

- 57/58—GRINDLEY, G. W.; HARRINGTON, H. J.: Late Tertiary and Quaternary Volcanicity and Structure in New Zealand. *Abstr. 9th Pacif. Sci. Congr.*: 120.

Two volcanic regions, comparatively stable tectonically and characterised by high-angle normal faulting, are separated by a more mobile non-volcanic region characterised by steep clockwise transcurrent faulting. The northern volcanic region comprises the north-west half of the North Island, and is divided into three petrographic and structural belts, striking north-west and a fourth striking north-east. Of the north-westerly provinces only the central basalt province remained active up to recent times (around Auckland city). In the late Pliocene or early Quaternary the north-east belt became active across the centre of the island, overlapping slightly the south-east ends of the earlier north-west belts. Activity has been continuous with further ignimbrite eruptions, rhyolite, dacite, and andesite volcanoes. Three andesite and one rhyolite volcanoes are still active, and thermal springs abound.

The north-west belts align with an older trend joining New Zealand to New Caledonia. The north-east belt aligns with the Kermadec-Tonga volcanic arc.

Tensional-transcurrent faulting and basins of thick post-Oligocene sedimentation characterise the negative-gravity belt lying to the south-east of the North Island volcanic region, while further to the south a wide belt of compressional-transcurrent faulting includes most of the young mountain ranges of New Zealand.

In the South Island, the volcanicity ranges from late Miocene to early Quaternary and lies in the stable east coastal area. The volcanoes are basaltic with trachytes and phonolites. (B.W.C.)

GUNN, B. M.; *See* 57/81.

- 57/59—HARRINGTON, H. J.: Size and Abundance of Phenocrysts in Lavas of Terrestrial and Geosynclinal Environments. (Letter to editor.) *Nature*, 179 (4553): 271.

In New Zealand several examples of thick assemblages of flows erupted on land and in adjacent shallow seas since the Miocene are all characterised by many large phenocrysts. Flows at several horizons among Cretaceous sediments deposited in deep marine basins or small geosynclines are dominantly even-grained, and aphyric or micro-phenocrystic. The degree of development of phenocrysts in flows interbedded with sediments of the major upper Paleozoic and lower Mesozoic geosyncline of New Zealand is also closely related to the position of the flow at the margin or near the axis of the geosyncline. (B.W.C.)

HARRINGTON, H. J.: *See also* 57/58 and 57/67.

HARRIS, J. W.: *See* 57/108.

- 57/60—HATHERTON, T.: Shallow Subsurface Prospecting by the Electrical Resistivity Method at Balclutha. *N.Z. J. Sci. Tech. B*, 38 (8): 807-19, 10 figs.

The electrical resistivity method has been used at Balclutha to investigate subsurface conditions, in connection with a flood-control scheme. It has been found possible, using the results of step-traverse surveys, to give a qualitative indication of areas of possible hydraulic-pressure danger. By coupling these step-traverse resistivity measurements with known bore-hole sections, a correlation has been obtained which enables the depth of overlying silt at any resistivity station to be estimated. It is shown that subsurface conditions in this area are such that the permeabilities of the formations cannot be determined from the resistivity data in this area. (Author's abstract.)

- 57/61—HAYAMI, I.: *Radulonectites*, a New Pectinid Genus, from the Liassic Kuruma Group in Central Japan. *Trans. Proc. palaeont. Soc. Japan*, 27 (n.s.): 89-93, 1 pl.

"*Chlamys*" *kakanuia* Marwick 1956 (Kaihikuan, Mid-Triassic of New Zealand) resembles the genus *Radulonectites* Hayami n. gen. (type: *R. japonicus* Hayami n. sp., Liassic, Japan) though classification in *Radulonectites* is not warranted at present. (C.A.F.)

57/62—HERDMAN, H. F. P.: Recent Bathymetric Charts and Maps of the Southern Ocean and Waters around Antarctica. *Deep Sea Research*, 4 (2): 130-7.

The U.S. Hydrographic Office Chart No. 2562 (3rd ed.) includes the seas around New Zealand and southwards to Antarctica. The new editions of the charts south of 46° 40' S. published by the International Hydrographic Bureau (the Monaco charts) extend southwards from the latitude of Stewart Island. The new revised edition of the Australian Map of Antarctica (1955) extends almost to Wellington, and is accompanied by a handbook of historical information. The German Karte der Antarktis (1955) is in four sheets with their northern limit at 63° S. Some comparisons are made of interpretations of relief of the ocean floor, and reference is made to the work of an international committee and national sub-committees on the naming of relief features of the ocean floor. (H.J.H.)

57/63—HILL, D.: The Sequence and Distribution of Upper Paleozoic Coral Faunas. *Aust. J. Sci.* 19 (3a): 42-61, 1 fig.

In a general review of the subject references are made to New Zealand. In the early Couvinian there are signs of a New Zealand and south-east Australian sub-province (of the Eurasian province) with a relatively high percentage of endemic genera. The Reefton fauna is a reduced representative of this sub-provincial fauna. The only post-Devonian coral faunas in New Zealand are a doubtfully Artinskian one from the south of the South Island, including *Rotiphyllum* and *Eurphyllum*, whose affinities are probably mostly with Australia; and possibly Kungurian or Kazanian colonial Rugosa from the north of the North Island. The distribution of coral reefs in Upper Paleozoic, Mesozoic, and Recent Times is discussed and illustrated by a map. (C.A.F.)

57/64—HODGSON, J. H.: Nature of Faulting in Large Earthquakes. *Bull. Geol. Soc. Amer.*, 68 (5): 611-43, 22 figs.

This paper is an explanation for geologists of the theory and practice of the Ottawa project for determining the direction of faulting in earthquakes from first-motion data. The method of analysis determines the attitudes of two intersecting planes either of which could be the fault, but does not determine which of these two planes is the fault. The intersection of the planes, however, is a unique line, called by Hodgson the "null vector", which undergoes no displacement. Previously published analyses of 75 earthquakes are tabulated and discussed, including 13 from the New Zealand-Tonga-Fiji area. These 13 all show strike-slip faulting and their null vectors are parallel to the associated geographical feature. A geological interpretation is given in an accompanying paper by McIntyre and Christie (see 57/84). (H.J.H.)

HODGSON, L.: See 57/102.

HOLLOWAY, J. T.: See 57/50.

57/65—HOOKER, Marjorie: Data of Rock Analyses. III - New Zealand Periodical and Serial Literature. Bibliography and Index of Rock Analyses. *Geochim. Cosmochim. Acta*, 11 (1-2): 130-7.

This paper consists of three lists: (1) periodical and serial literature containing geological papers and published in New Zealand; (2) references to 78 New Zealand papers in which new chemical analyses of igneous or metamorphic rocks are published; and (3) an alphabetical rock-name index to these papers. (H.J.H.)

57/66—HOPGOOD, A. M.: Spherulitic Jaspilite from Whangarei Heads. *Trans. roy. Soc. N.Z.* 85 (1): 131-4, 1 pl., 1 fig.

Spherulitic jaspilite occurring in small lenses at McLeod Bay, Whangarei Heads, is closely associated with fine-grained spilitic rocks. Individual spherulites exhibit both concentric and radial form and show crowding of haematite and minute silica particles into concentric zones. The location of the jaspilite as xenoliths within spilite indicates that banded haematite cherts caught up by the spilite have been partially dissolved and recrystallised to their present spherulitic form. (Author's abstract.)

HORNIBROOK, N. de B.: See 57/45 and 57/108.

57/67—HORNIBROOK, N. de B., and HARRINGTON, H. J.: The Status of the Wangaioan Stage. *N.Z. J. Sci. Tech., B*, 38 (6): 655–70, 6 figs.

Shallow-water carbonaceous sands and mudstones deposited along the eastern side of the South Island during the uppermost Cretaceous, Paleocene, and Lower Eocene are difficult to correlate with the standard New Zealand sequence because of facies control of their faunas. The previous correlation of part of the Te Uri section and of the Waipawa Black Siltstone with the Wangaioan Stage cannot be sustained. The Teurian Stage and the Dannevirke Series are believed to be a complete Danian-Lower Eocene sequence of which some part must be the equivalent of the Wangaioan Stage. It is proposed that the Wangaioan henceforth be omitted from the standard sequence of stages in New Zealand. (Authors' abstract.)

57/68—HUTTON, C. O.: Contributions to the Mineralogy of New Zealand. Part 4. *Trans. roy. Soc. N.Z.*, 84 (4): 791–803, 2 figs.

Rhodonite-spessartite-rhodochrosite schists from Arrow Valley, Western Otago, are described. Chemical analyses and physical data for spessartite and rhodonite are presented. It is believed that these schists are the Chlorite Zone equivalents of manganeseiferous sediments precipitated by submarine volcanic action.

Xenotime and gahnite are reported from placer deposits at Port Pegasus, Stewart Island. Physical characteristics, including X-ray diffraction data, of the xenotime are compared with those of the same mineral from Banka, Indonesia. The gahnite is compared with gahnite from Japan and gahnspinel from Ceylon. (From author's abstract.)

57/69—HUTTON, C. O.: Kobeite from Paringa River, South Westland, New Zealand. *Amer. Mineral.* 42 (5–6): 342–53, 3 figs.

A tantalum-niobium-titanium-bearing mineral has been found as slender prismatic crystals in a cobble of graphic granite in gravels of the Paringa River. The mineral is dark brown in colour and metamict, with the characteristic resinous lustre and strikingly conchoidal fracture of a mineral in that state. The refractive index is 2.205 but after being heated to 1,200°C in vacuo a value of 2.35 was recorded; specific gravity is close to 5. X-ray diffraction patterns secured from unheated and carefully heated fragments are either identical to or exhibit insignificant differences from powder photographs obtained with similarly treated kobeite from the type locality of Shiraishi, Kyoto Prefecture, Japan. On the basis of these details, but in the absence of quantitative analytical data, the South Westland mineral is considered to be identical with, or very closely related to, kobeite. The source of the pebble is uncertain but it has probably been derived from granitic stocks or pegmatites that are known to outcrop in this general area. (Author's abstract.)

57/70—KEAR, D.: Kauaeranga Sulphide Deposit, Thames. *N.Z. J. Sci. Tech. B*, 38 (6): 483–95, 4 figs.

A north-east-striking belt of iron sulphide mineralisation, in rocks of the Beesons Island Group of the Kauaeranga Valley, has been prospected. Carbonaceous beds, and probably other suitable horizons, were preferentially mineralised, by replacement, with pyrite and marcasite. Drilling and sampling have indicated between 15,000,000 and 20,000,000 tons of rock, above stream level, with an average of between 7% and 8% sulphur. The deposit seems too low grade to be worked economically under present conditions. Plant microfossils from the mineralised belt are of a Taranaki to lower Wanganui age. (From author's abstract.)

57/71—KEAR, D.: Erosional Stages of Volcanic Cones as Indicators of Age. *N.Z. J. Sci. Tech. B*, 38 (7): 671–82, 4 figs.

Four stages in the erosion of volcanic cones are defined, and those factors, other than age, that might affect present cone shape, are discussed. Where no such factor is abnormal, the erosional stage of a cone is considered to be diagnostic of its age. This method of age determination must be calibrated by many indirect, as well as direct, datings, and therefore the following age ranges of the four stages for North Island

cones must be subject to future amendments: Volcano Stage, Holocene; Planeze Stage, Castlecliffian to Holocene; Residual Mountain Stage, Wanganui Series; and Skeleton Stage, Taranaki to lower Wanganui. (Author's abstract.)

- 57/72—KEAR, D.: Stratigraphy of the Kaawa-Ohuka Coastal Area, West Auckland. *N.Z. J. Sci. Tech. B*, 38 (8): 826-42, 6 figs.

Mesozoic and Oligocene stratigraphy and structure in the Kaawa-Ohuka coastal area, West Auckland, are described, and its Oligocene rock unit terminology is revised. Special emphasis is given to Pliocene and Pleistocene stratigraphy. In the field, no break is recognised between the Opoitian Kaawa Shellbed and the Nukumaruan Ohuka Carbonaceous Sandstone. The cool climate indicated by the flora obtained from the latter formation is correlated with the Ross Glaciation, and is considered older than the formation of the widespread 550 ft terrace on the Kaihu Formation. Sea-level at the Pliocene-Pleistocene boundary is tentatively estimated as between 100 and 300 ft. (Author's abstract.)

- 57/73—KEAR, D.: Pumice Chronology in New Zealand. *N.Z. J. Sci. Tech. B*, 38 (8): 862-70, 2 figs.

The distribution of conspicuous pumice in North Island rocks is described and illustrated within the framework of Finlay and Marwick's series and stages. It is most simply explained by: a northern andesitic source, nearest to Kaipara Harbour, which was active in the lower Southland; a source that was active in the upper Southland and Taranaki, probably to the south-east; and a central rhyolitic source in which the eruptive centres shifted southwards from near Cape Colville Peninsula in the lower Wanganui, to Rotorua-Taupo in the upper Nukumaruan to Holocene. (Author's abstract.)

- 57/74—KEAR, D.: Geological Techniques in Dating New Zealand's Prehistory. *N.Z. Sci. Rev.* 15 (9-10): 76-79.

A shell bed on the Hauraki Plains, about 10 ft above sea-level, has been carbon-dated as $2,270 \pm 70$ years B.P. This retreat of the sea, which can be recognised by several independent methods, is a suitable base for New Zealand's archaeological time scale. Climatic changes since the Thermal Maximum are reflected in sequences of vegetation and of faunas. Methods using normal geological processes, including coastal progradation, alluvial deposition, sedimentation in lakes and swamps, ash showers, and earthquakes are described. Use of the radiocarbon method of dating is illustrated. (W.F.H.)

- 57/75—KEAR, D., and TOLLEY, Wendy P.: Notes on Pleistocene and Jurassic Beds near Morrinsville. *N.Z. J. Sci. Tech. B*, 38 (6): 500-6, 2 figs.

Pleistocene plant microfossils from a depth of 442-620 ft in a drillhole at Morrinsville are dated as younger than lower Nukumaruan. They indicate a cool period which is correlated with that of the uppermost Nukumaruan to lower Castlecliffian. The great thickness of Quaternary strata (at least 940 ft) is attributed to Pleistocene subsidence of the Hauraki Depression and a great supply of rhyolitic sediment.

Ohauan fossils (upper Jurassic) are recorded from the Manaia Hill Group. (Author's abstract.)

- 57/76—KINGMA, J. T.: The Geology of the Kohurau Fault Block, Central Hawke's Bay. *N.Z. J. Sci. Tech. B*, 38 (4): 342-53, 6 figs (incl. geol. map).

The Kohurau Graben is situated between the north-east-trending Kaweka and Ruahine faults in the high country of western Hawke's Bay. Prior to its formation, the region was crossed by an earlier, south-east-striking graben - the Kuripapanga Graben. Pliocene beds immediately overlie a greywacke undermass. Lower Pliocene (Opoitian) strata are confined to the Kuripapanga Graben, whereas upper Pliocene (Waitotaran) beds were deposited over the entire area. The structure of the floor of the Kohurau Graben is complicated by overthrusting. Dextral transcurrent movement started on the Ruahine fault immediately after the Waitotaran sediments were deposited. (Author's abstract.)

- 57/77—KINGMA, J. T.: The North Island Geanticline in the Hawke's Bay Sector. *N.Z. J. Sci. Tech. B*, 38 (6): 496-9, 1 pl. (geol. sects.)

The North Island Geanticline commenced to rise late in the Cretaceous, and emerged in the lowest Eocene. Its rise continued until the Pliocene, when it sub-merged, and Pliocene sediments were deposited on its peneplained crest. In the lower Pleistocene the geanticline re-emerged rapidly to form the present main range in the Hawke's Bay sector. (Author's abstract.)

- 57/78—KINGMA, J. T.: The Tectonic Setting of the Ruahine-Rimutaka Range. *N.Z. J. Sci. Tech. B*, 38 (8): 858-61, map.

The Ruahine-Rimutaka Range is a horst. Situated on the eastern flank of the North Island Geanticline, this mountain chain is structurally not an axial range. In addition to vertical movement, there has also been dextral transcurrent movement along the bordering faults. During the Kaikoura diastrophism in early Pleistocene time, the horst moved southwards. (Author's abstract.)

- 57/79—KNOX, G. A.: General Account of the Chatham Islands 1954 Expedition. *N.Z. Dep. sci. industr. Res. Bull.* 122. 37 pp., 24 figs., 2 charts.

Includes sections on bottom topography (p. 9) and geology (pp. 9-11), mainly summarising the work of previous investigators. See also abstract 57/11 (appendix on marine geology by J. W. Brodie.)

- 57/80—KOBAYASHI, T.; NAKANO, M.: On the Pterotrigoniinae. *Jap. J. Geol. Geog.* 28 (4): 219-38, 2 pls.

The Pterotrigoniinae are tentatively classified in three genera: *Pterotrigonia* van Hoepen (with subgenus *Rintetrigonia* van Hoepen); *Scabrotigonia* Dietrich; and *Acanthotrigonia* van Hoepen. *Trigonia pseudocundata* Hector (Senonian, New Zealand) is listed under *Pterotrigonia*, which was cosmopolitan in the early Cretaceous but known in the late Cretaceous only in North America and New Zealand. *T. waiparaensis* Woods (classed as *Oistotrigonia* by Cox), also from the Senonian of New Zealand, is listed under *Acanthotrigonia*. (C.A.F.)

- 57/81—LILLIE, A. R.; GUNN, B. M.; and ROBINSON, P.: Structural Observations in Central Alpine Region of New Zealand. *Trans. roy. Soc. N.Z.*, 85 (1): 113-29, 7 pls., 2 figs.

The strata, ranging in metamorphic grade from sandstones and argillites of Chlorite 1 sub-zone to garnet-biotite schists, are strongly folded, generally with axes trending N. 30° E. In the east of the area, isoclinal folds in less metamorphosed rocks dip steeply north-west; in the west, folds in the more highly metamorphosed rocks are more steeply inclined to the south-east. There is thus a fan-like disposition of folds.

In the less metamorphosed rocks cleavage is parallel to bedding planes or nearly so. Towards the west, axial plane schistosity (cleavage) becomes very marked. On steeply-dipping limbs, where schistosity and bedding planes are nearly parallel, patterns of drag folds indicate the positions of major fold axes; but in other places, especially on the crests of major folds, the beds are extremely corrugated and the plane (S_2) schistosity surfaces cut across the bedding schistosity. Lineations mask the intersections of stratification and schistosity.

Boundaries of metamorphic zone cut obliquely across the trend of schistosity planes. Simple relations between stratigraphic depth and grade of metamorphism have not been established. While metamorphic grade may tend to increase in older rocks, it seems likely that beds of the same horizon occur in different metamorphic zones.

Certain metamorphic rocks are less structurally deformed than others of lower grade. Metamorphism and some folding probably preceded a later phase of metamorphism connected with the formation of schistosity and corrugations.

Especially in the western part of the area there are a great many faults, throwing the western blocks successively upwards in relation to the eastern blocks. There is no evidence to suggest that a low-angle thrust plane was formed, and the degree of shortening of the beds is not comparable to that of the European Alps.

Locally the strike of strata swings considerably from the general trend, and such swings are probably connected with folds of very steep plunge to the north-west. These folds are not necessarily the result of a later superimposed folding but may be cross-buckles formed at localities where distinct changes in intensity of regional stress occurred. The paper is illustrated by photographs and sketches, a structural map, and diagrammatic cross-sections. (Author's abstract modified and extended.)

57/82—LINTON, D. L.: Radiating Valleys in Glaciated Lands. *Tijdschr. Kon. Nederl. Aardrijksk. Gen.* 74 (3): 297–312, 4 figs, 3 maps.

One of the regions discussed is the Fiordland District of New Zealand (pp. 307–9, map), citing the work of Benson. (B.W.C.)

LLOYD, E. F.: See 57/5 (4).

MCCREE, K. J.: See 57/5.

57/83—McGLASHAN, T. B.: Site Investigation Equipment and Methods Adopted by the Auckland Harbour Board. *N.Z. Engng.* 12 (1): 21–31, 15 figs.

The latest borings for the proposed Cargo Wharf east of the Import Wharf revealed two distinct layers of sandstone – the lower, the true Waitemata Series of mid-Tertiary times, and an upper layer of Pleistocene origin – separated at many places by clay deposits many feet thick. Methods described include: sounding, percussion wash-boring, and dredge sampling. (B.W.C.)

57/84—McINTYRE, D. B.; CHRISTIE, J. M.: Nature of the Faulting in Large Earthquakes. *Bull. geol. Soc. Amer.* 68 (5): 645–52, 4 figs.

This paper is complementary to, and a geological interpretation of, the paper by Hodgson with the same title (see 57/64). It is shown that the null vector of Hodgson is the B kinematic axis. The determinations of B for the New Zealand-Kermadec-Tonga-Fiji region are plotted on a Lambert equal-area projection and it is shown that they lie on a nearly vertical plane which "contains the physiographic feature" (sic). It is concluded that of the two planes determined by Hodgson for each earthquake in this sector of the circum-Pacific belt, those with north-easterly strikes are the faults. (H.J.H.)

57/85—McMICHAEL, D. F.: A Review of the Fossil Freshwater Mussels (Mollusca, Pelecypoda) of Australasia. *Proc. Linn. Soc. N.S.W.* 81 (3): 222–44, 2 pls., 1 fig.

The name (?) *Velesunio buttoni* nom. nov. is proposed for *Unio inflata* Hutton 1873 (not of Studer, 1820, etc.) from the Whaingaroan (Oligocene) of Ohai, Southland. The genus *Velesunio* does not live in New Zealand but belongs to a primitive sub family that has been in Australia since the Triassic. Impressions from shale (?Taranaki Series – Miocene) in the Kowari River, Cromwell, Otago, closely resemble the living *Hyridella aucklandica* and *H. menziesi*. The new genus *Protovirgus* is proposed for *P. dunstani* (Etheridge, jun.), type, from the Triassic of New South Wales, and *P. flemingi* n. sp. from the Paparoa Coal Measures (Upper Cretaceous) of Morgan Mine, Rewanui. Another undescribed specimen from the Paparoa beds resembles Recent hyridelline species. The author concludes that much more material must be studied before the fossil freshwater mussels of the region are properly known. (C.A.F.)

McQUEEN, D. R.: See 57/108.

57/86—MARWICK, J.: New Zealand Genera of Turritellidae, and the Species of *Stiracopus*. *N.Z. geol. Surv. Pal. Bull.* 27. 55 pp., 5 pls., 5 figs.

Part 1: Genera of New Zealand Turritellidae (pp. 5–20).

The need for generically subdividing the broad Lamarckian genus *Turritella* is emphasised and the criteria for doing this are discussed. These are: the shape of the outer lip of the aperture; the manner of development of the spiral sculpture, especially on the neanic whorls; and the kind of protoconch. The restricted dispersal ability of the family in general, and the influence of this on taxonomy are pointed out, and the seven New Zealand Danian to Recent genera and subgenera that have been named are described and figured.

Part 2: Living and Fossil Species of *Stiracolpus* (pp. 21–50).

A description of the known occurrences and supposed relationships of 29 species and subspecies of *Stiracolpus*, a Pliocene to Recent subgenus of *Zeacolpus*, is followed by a systematic description of the different forms, each of which is figured. The descriptions are based mainly on the way in which the spiral sculpture develops. (Author's abstracts.)

57/87—MARWICK, J.: Generic Revision of the Turritellidae. *Proc. Malacol. Soc.*, 32 (4): 144–66, 70 figs.

The genus comprises more than 1,000 named species and subspecies, ranging in age from the Lower Cretaceous, perhaps Jurassic, to Recent, and distributed throughout the world. It is thus too comprehensive to be very useful in taxonomy, stratigraphy, or palaeogeography.

The Turritellidae have, in general, restricted dispersal ability, so that genetically isolated groups, in Cretaceous and Tertiary time, must have diverged widely from each other. The most reliable criteria for classifying the family appear to be: (1) the trace of the outer lip; (2) the ontogeny of the primary spirals; (3) the protoconch. These criteria are discussed at some length.

The main part of the paper consists of taxonomic notes on named groups (genera and subgenera) classified into five subfamilies: Turritellinae (Woodward, 1851), Protaminae (nov.), Pareorinae (Finlay and Marwick, 1937, as a family), Turritellopsinae (nov.), and Orectospirinae (Habe, 1955). Recommended genera and subgenera are distinguished by type face from invalid homonyms and synonyms. (B.W.C.)

57/88—MARWICK, J.: Note on the Revision of the Turritellidae. *Proc. malacol. Soc.*, 32 (5): 206.

Neodiastoma Cotton (South and West Australia) is transferred from the Turritellidae to the Diastomatidae. This latter family was proposed, not by Wenz, but in 1895 by Cossman (as Diastomidae). (B.W.C.)

57/89—MASON, B.: Larnite, Scawtite, and Hydrogrossular from Tokatoka, New Zealand. *Amer. Mineral.* 42 (5–6): 379–92, 2 figs.

A limestone of the Onerahi Formation (Lower Tertiary) near Tokatoka, Northland, has been metamorphosed by an andesite dyke. A marked mineralogical zoning parallel to the contact has been produced, the succession outwards consisting of rock rich in (1) hydrogrossular (thickness 6 in.), (2) larnite (30 in.), and (3) scawtite (10 in.). Other minerals recognised include cristobalite, opal, spurrite, gehlenite, and wollastonite. The minerals are described in detail and their paragenesis discussed. It is estimated that the maximum temperature during metamorphism was about 800°C. Chemical analyses and descriptions are given of the andesite, hydrogrossular-cristobalite rock, larnite rock, scawtite rock, and slightly metamorphosed limestone 8 ft from the contact. The high content of 1.26% BaO in the andesite is noteworthy. The larnite does not revert to gamma dicalcium silicate on heating or hammering and is the first record of the beta form outside Great Britain. The name hydrogrossular is applied to the continuous series of minerals with compositions between $\text{Ca}_3\text{Al}_2\text{Si}_3\text{O}_{12}$ and $\text{Ca}_3\text{Al}_2(\text{OH})_{12}$, to the exclusion of other names for parts of this series. (Author's abstract modified and extended by H.J.H.)

57/90—MUTCH, A. R.: Facies and Thickness of the Upper Paleozoic and Triassic Sediments of Southland. *Trans. roy. Soc. N.Z.*, 84 (3): 499–511, 8 figs. (incl. geol. map).

The stratigraphy of the Southland Upper Paleozoic-Triassic sequence is described and illustrated by columnar sections. Facies changes indicate the former existence of an old landmass beyond the southern margin of the Southland Syncline and a geosyncline beyond the northern margin. Two major marginal unconformities are described. The north-east thickening of the Lower Permian and Triassic beds is shown by isopach maps. The relation of the beds to the geosyncline and to the Otago Schist is discussed. Rocks of the same age exhibit progressive increase in metamorphism and deformation towards the Otago Schist, and the thicknesses of the Upper Paleozoic and Triassic beds indicate a corresponding increase in depth of burial. (Author's abstract.)

NAKANO, M.: See 57/80.

OLSON, O. P.: See 57/47.

57/91—PACKARD, R. Q.: Some Physical Properties of Taupo Pumice Soils of New Zealand. *Soil Sci.* 83 (4): 273–89, 5 figs.

Physical analyses of 10 soil types formed on pumice sands of the Taupo ash shower showed high organic matter and low bulk density compared with other mineral soils. Taupo ash, produced by cataclysmic eruptions about 1,700 years ago, covers 8,800 square miles at a thickness of more than 6 in. Mechanical analyses, porosities, and moisture relations are discussed. (B.W.C.)

57/92—PANTIN, H. M.: Fossiliferous Concretions from the Shelf South-East of Cape Campbell, New Zealand. *N.Z. J. Sci. Tech. B.* 38 (7): 781–91, 4 figs. (With an appendix, "Notes on the Paleontology of the Concretions" by A. E. Boreham and C. A. Fleming, pp. 788–91.)

Calcareous concretions containing abundant fossils have recently been dredged from the shelf near Cape Campbell. The concretions appear to have formed originally in a silty clay or mudstone, which has since been removed by erosion. The presence of certain critical species indicates that the enclosed fossils lived under a climate colder than that of the present day. The shelly fauna from one concretion has been shown, by means of a ^{14}C determination, to have lived about 19,500 years ago. A ^{14}C determination on the calcareous matrix of the same concretion shows that the calcite in the matrix cannot represent a direct precipitate from the sea; it was probably derived from older sediments, some of which must have been at least 8,000 years older than the fauna in the concretions.

The appendix consists of paleontological and ecological notes. The most abundant shells, *Chlamys delicatula* and *Aulacomya*, have not been described as dominant members of a Recent bottom community. Most of the species listed have a wide depth tolerance. The faunal assemblage differs markedly from those from concretions recorded from other parts of the Cook Strait region. (Author's abstract extended by B.W.C.)

PHILLIPPS, W. J.: See 57/50.

POHLEN, I. J.: See 57/13 (3).

57/93—POWELL, A. W. B.: "Shells of New Zealand: an Illustrated Handbook". 3rd ed. Whitcombe and Tombs, Christchurch. 202 pp. 36 pls., many figs.

This enlarged edition of the author's "Shellfish of New Zealand" (1937, 1946) contains a section (pp. 23–5) on "Interpreting the Geological Past by Means of Our Fossil Mollusca" and refers incidentally to fossil and sub-fossil species. (B.W.C.)

57/94—PRIDER, R. T.: E. de C. Clarke (Obituary). *Aust. J. Sci.* 19 (5): 193–5.

A brief biography and appreciation of the work of the former Professor of Geology in the University of Western Australia by his successor. Clarke was born and educated in New Zealand and an officer of the New Zealand Geological Survey from 1907 to 1910, during which time he worked in the Nelson, Auckland, and Taranaki districts. From 1910 to 1912 he was on the staff of Auckland University College, and then with the Geological Survey (1912–1920) and University (1920–1948) of Western Australia. There is a bibliography of his geological publications. (B.W.C.)

57/95—RAFTER, T. A.: Radio-carbon Ageing in New Zealand. *N.Z. Sci. Rev.* 15 (11–12), 93–96.

Following an outline of principles, the enrichment of the atmosphere, of sea-water and of shell-carbonates in ^{14}C due to the "isotope effect", and the "industrial effect" of the combustion during the last 100 years of enormous quantities of fossil carbonaceous fuel containing no ^{14}C , are discussed. In conclusion some practical advice on the collection and forwarding of samples for age-determination are given. (W.F.H. and B.W.C.)

RAFTER, T. A.: See also 57/35.

57/96—REED, J. J.: Fault Zones in Part of the Rimutaka Range. *N.Z. J. Sci. Tech. B*, 38 (7): 686–7, 2 figs.

Five crush zones encountered during the driving of the Rimutaka railway tunnel are correlated with surface faults. In one zone gas seepages were noted. The crush zones, where wet, provide very difficult tunnelling conditions. (Author's abstract.)

57/97—REED, J. J.: Use of the Terms Greenstone, Nephrite, Bowenite, and Jade. *J. polynes. Soc.* 66 (2): 204–5.

"Greenstone" is advocated as a general term for both nephrite and bowenite. Jade is not synonymous with greenstone, but includes jadeite and nephrite. Where the mineral variety is known, the terms nephrite, jadeite, and bowenite should be used. (D.R.G.) See abstracts 56/2 and 105, and also 57/119.

57/98—REED, J. J.: Petrology of the Lower Mesozoic Rocks of the Wellington District. *N.Z. geol. Surv. Bull.* 57, 60 pp. 36 figs.

The rocks (Triassic?) consist mainly of unfossiliferous greywackes (sandstones) and argillites (siltstones) with locally abundant intraformational conglomerates and intercalated submarine spilitic lavas, red and green volcanic argillites, radiolarian jaspers, and grey cherts.

The most characteristic microtextural features of the greywackes are poor sorting and the pronounced angularity of the clastic grains. The rocks are siliceous, with more soda than potash. The nature of the rock fragments and the assemblage of quartz, alkali feldspar, and biotite indicate derivation mainly from a plutonic terrain of granite, gneiss, and metamorphic rocks. The Wellington greywackes and similar rocks of the axial ranges of New Zealand (Alpine Facies) differ from the rocks of the Hokonui Facies in their paucity of rock fragments and volcanic debris. The Wellington rocks also show small but distinct chemical and mineralogical differences from the lower Palaeozoic and pre-Cambrian greywackes of the Reefton and Lyell districts (principally the higher proportion of clastic feldspar to clastic quartz in the Wellington rocks).

The argillites have the same microtextural features as the greywackes but on a finer scale. They differ in having more potash than soda, slightly more alumina, and slightly less silica.

The intraformational conglomerates consist of: (1) rounded to sub-angular pebbles in an argillaceous matrix; (2) argillite fragments in a sandstone matrix; or (3) sparse rounded pebbles set in an argillaceous matrix containing angular clastic grains. The third type is regarded as a pseudo-tillite.

The term autoclastic breccia is applied to well-indurated crush breccias resulting from fracture, folding, and shearing, during the first main period of deformation—the post-Hokonui Orogeny of early Cretaceous age. The incompetent argillite layers acted as a mobile medium in which broken fragments of more competent rocks were scattered.

The intercalated submarine lavas and the volcanic argillites are also described and their origin discussed.

The greywackes, argillites, and conglomerates are considered to belong to Fischer's Wacke class of poorly-assorted sediments. The greywackes are well-indurated, felspathic (arkosic) meng and quartz-meng sand-wackes.

The rocks of the Wellington district belong to a marine geosynclinal association found in many parts of the world. Probably the greywackes and argillites were transported from shallow water and redeposited in deep water by turbidity currents.

An Appendix describes and discusses the petrographic calculations and chemical analyses. (From author's summary.)

57/99—REED, J. J.; CLARIDGE, G. C.: Identification of Coffinite in Radioactive Rocks of the Buller Gorge Region, New Zealand. *Nature*, 179 (4558): 546.

A short note recording the identification of the mineral by its characteristic X-ray pattern in radioactive lower Cretaceous arkosic grits and siltstones. (B.W.C.)

- 57/100—REILLY, W. I.: Convergence During Cutting of a Longwall Coal Face. *N.Z. J. Sci. Tech. B*, 38 (9): 982-91, 8 figs.

Observations at the Mangapehi State Coal Mine show that the observed convergence at a face prop is due partly to the load released directly from the coal cut, and partly to the load released by the non-elastic yielding of the coal in the newly-exposed face. (From author's abstract.)

- 57/101—REILLY, W. I.: Fracturing of the Roof Strata in Coal Mines. *N.Z. J. Sci. Tech. B*, 38 (9): 992-1,000, 5 figs.

The infrequent instantaneous movements recorded in coal mines are related to fractures in the strata, and may give some warning of an impending fall of roof. The energy released by these fractures, however, is insufficient to cause the widespread tremors reported in some mines, the origin of which must be sought either in extensive roof-falls, or in extensive fracturing within the covering strata between the coal seam and the surface. (Author's abstract modified.)

- 57/102—RIGG, T.; CHITTENDEN, E.; HODGSON, L.: "A Survey of Soils, Vegetation, and Agriculture of the Eastern Hills, Waimea County, Nelson." Cawthron Institute, Nelson. 42 pp. 5 pls. 4 maps.

Includes (pp. 7-9) a short section on geology with special reference to the soil type and vegetation typical of the various formations present. Summarises Wellman's (MS) reclassification of the beds of the Maitai and Te Anau Groups, and briefly describes his four sub-divisions of the Maitai (Permian) rocks - Rangitoto, Greville, Waiua, and Stevens formations. (B.W.C.)

ROBERTSON, E. I.; See 57/13 (1).

ROBINSON, P.: See 57/81.

- 57/103—SANDERS, C. A. I.: White Island. *N.Z. alpine J.* 17 (44): 99-106, 1 photo.

Describes a visit in March 1954. The present crater area contains probably the finest thermal area in New Zealand. The rocks are andesites, and there is evidence of a long history of alternating volcanism and quiescence dating back at least into the Pleistocene. A lahar in September 1914 left a large number of conical mounds on the floor of the crater. The history of the working of sulphur deposits on the island is described, including the destruction of the works with the loss of 11 lives by the 1914 eruption. It is stated that no economic deposits of sulphur are now left. Acknowledgment is made to a report by J. Healy and J. Luke (1947), and to a bulletin (in press) by W. M. Hamilton and I. L. Baumgart. (B.W.C.)

- 57/104—STEVENS, G. R.: Solifluxion phenomena in the Lower Hutt area. *N.Z. J. Sci. Tech. B*, 38 (4): 279-96, 15 figs.

In the Hutt Valley, near Wellington, distinctive solifluxion features appear to be related to altitude, slope gradient, and the presence in the topography of Kaukau Surface remnants. A high-level type of solifluxion occurred on more or less horizontal remnants of the Kaukau Surface at altitudes above 1,000 ft (305 m); here the movement of regolith particles was dominantly in a vertical sense. Towards the margins of the surface remnants, however, lateral (i.e. down-slope) movement gradually predominated and *coulées* of soliflual debris, dells, and "head"-filled gullies were developed. At lower levels (arbitrarily below 600 ft (180 m)) thaw-water streams probably assumed local importance and a type of soliflual-debris deposit partly water-sorted is recognised. Probable congelifractate fans are also described. (Author's abstract slightly modified.)

- 57/105—STEVENS, G. R.: Geomorphology of the Hutt Valley, New Zealand. *N.Z. J. Sci. Tech. B*, 38 (4): 297-327, 25 figs.

The geomorphology of the Wellington Fault zone is discussed mainly on the basis of stream profiles for the eastern and western sides of the Hutt Valley. Three types of stream profile may be distinguished in the streams of the western valley-side, depending on the effects of fault shatter-zones and up-faulting of basement rocks.

Of down-stepping flats on spurs on the eastern valley-side and around Port Nicholson the lower and better defined are perhaps of marine (eustatic) origin, but some such benches at higher levels may be fault-controlled.

The ancestral river system of the western part of the Hutt Valley has been profoundly affected by movements in the Wellington Fault zone. Air-gap valleys of this system are conspicuous in the present-day topography of the western side of the valley.

The Late Tertiary and Quaternary geological history of the Hutt Valley is summarised. (Author's abstract.)

57/106—STINTON, F. C.: Teleostean Otoliths from the Tertiary of New Zealand. *Trans. roy. Soc. N.Z.* 84 (3): 513–7, 1 pl.

Eleven new species of Tertiary Teleostean fish otoliths are described and figured. Most are referred to living subantarctic deep-water groups, suggesting that the beds in which they occur are of deep-water origin. (Author's abstract extended.)

57/107—STUDT, F. E.: Wairakei Hydrothermal System and the Influence of Ground Water. *N.Z. J. Sci. Tech. B*, 38 (6): 595–622, 8 figs.

The Wairakei hydrothermal system is discussed, more especially in relation to the influence of ground water, which is important in the permeable pumiceous formations. Comparison is made with other areas, notably in Italy and Iceland. Characteristics of drillholes tapping the steam and hot water are examined, and deductions are made about future trends resulting from exploitation. (Author's abstract.)

57/108—SUGGATE, R. P.: The Geology of the Reefton Subdivision (Reefton Sheet, S38). *N.Z. geol. Surv. Bull.* 56. 148 pp., frontispiece + 36 figs.; 8 geol. maps and 2 sheets sections in separate covers.

The rocks of this area in north-west Westland and south-west Nelson range in age from pre-Cambrian to Late Quaternary, and present diverse geological problems, some of which remain unsolved.

The district comprises three distinct physiographic regions – the Paparoa Range, the Grey-Inangahua Depression, and the Victoria Range Foothills. The first-named rises to nearly 5,000 ft and shows glacial sculpture in the higher parts. Folded early Pleistocene gravels occupy the greater part of the central depression, which is of tectonic origin, and within the depression terraces at different levels up to several hundred feet above the rivers record a complex sequence of Late Pleistocene glacial fluctuations. Only two western spurs of the Victoria Range extend into the district, but a wide belt of foothills lies between these and the Grey-Inangahua Depression.

The oldest rocks, unfossiliferous indurated sandstone and mudstone, are mapped in two groups – the Waituta Group in the east and the Greenland group to the west. Both are thought to be of pre-Cambrian age. Granite, which together with gneiss forms the greater part of the Paparoa Range, intrudes both groups. Small areas of Reefton Group, of Devonian age, are faulted against all older rocks and contain limestone, mudstone, and quartzite.

The sequence of Cretaceous and Tertiary rocks has been the subject of various interpretations. Breccia-conglomerate, similar to the type Hawks Crag Breccia of the lower Buller Gorge, is probably basal Cretaceous, and associated with it is the Topfer Formation, coal measures of early Cretaceous age. Tertiary and early Pleistocene beds differ widely from one part of the district to another, and include coal measures, marine mudstone, sandstone, and siltstone, limestone, freshwater conglomerate, sand, and lignite, and fluviatile gravel and sand.

In detail the structure of the various age groups of rocks differs widely, but a north-north-east trend shows throughout, evidently having been passed on from one period of folding to the next. A significant feature is that later folding has been unable to obliterate or even significantly alter the patterns of earlier sets of folds. The most probable method of superimposing one series of folds on another without destroying the older structures is by slip along bedding and joint planes.

Faulting took place at many different periods, and aerial photographs of outwash gravel surfaces show numerous straight or gently-curved fault scarps of recent origin on the west side of the Grey-Inangahua Depression.

The coal resources of the district are considered in detail, and estimates given of total and recoverable coal in the various fields and mining districts. Regional variation of coal rank results in different utilisation of coal from each mining area. Prospects for future development are described. Other economic mineral deposits, the most important of which in the past has been gold, include also antimony, arsenic, limestone, clay, and gravel.

The bulletin is fully documented with an index of fossil collections, logs of coalfield drill holes, lists of coalmines, and tables of coal analyses. Methods of estimating coal reserves are described in an appendix.

Contributions by other authors include sections by C. A. Fleming (macrofossils), N. de B. Hornibrook (microfossils), R. A. Couper (plant microfossils), D. R. McQueen (plant macrofossils); and J. W. Harris (petrology). (B.W.C.)

- 57/109—SUMICH, J. J.: Notes of the Geology of the Poor Knights Islands. *Tane*, 1955-56, 1: 64-5.

The Poor Knights Islands represent the northern part of a tectonic line of extinct rhyolitic volcanoes that includes Mokohinau, Great Barrier, Cuvier, and Colville. They rise with precipitous cliffs from a depth of 20 fm or more, to a maximum height of 500 to 600 ft. Rhyolite lavas are present on Tawhiti Rahi and Aorangi, but rhyolitic breccias are predominant with minor occurrences of finer material. The location of the source volcanoes is generally inferred as being to the east of the present islands, although an apparent crater is described from Aorangi. No evidence of age is recorded, but the volcanism is assumed to be Miocene. An abandoned cave is reported 100 ft above sea level. (D.K.)

- 57/110—SWINDALE, L. D.: Some Recent Advances in Clay Minerals Research. *J. N.Z. Inst. Chem.* 21 (5): 128-38, 4 figs.

Increased understanding of the nature and properties of the clay minerals has been accompanied by advances in technology, new industrial uses, and increased appreciation of their importance in agriculture and civil engineering. This review summarises recent work on the structure of the kaolin group (including kaolinite, nacrite, dickite, halloysite, the serpentines, and amesite), the mica group (including muscovite, biotite, vermiculite, and montmorillonite), and the chlorites, and lists nineteen recent publications. (B.W.C.)

- 57/111—TE PUNGA, M. T.: A Conformable Sequence of Rocks of the Wanganui and the Hawera Series. *N.Z. J. Sci. Tech. B*, 38 (4): 328-41, loc. map.

Rocks of the Hawera Series rest conformably on the youngest beds of the Wanganui Series in the "Mingaroa Section", near Bulls in the Rangitikei Valley. As it has been customary in the past to consider that regional unconformity separates rocks of the Hawera Series from those of the Wanganui Series this important section is described in some detail. The record of continuous deposition of late Castlecliffian and Hawera marine sediments necessitates revision of previous ideas concerning the dating and interpretation of late diastrophic movements in Wellington Province. The Mingaroa fossil beds furnish interesting examples of the *Tawera* + *Glycymeris* community, the *Tawera* + *Venericardia* association, and the *Notocorbula* + *Pleuromeris* associations. All beds in the Mingaroa Section are assigned to the Pleistocene. (Author's abstract.)

- 57/112—TE PUNGA, M. T.: Live Anticlines in Western Wellington. *N.Z. J. Sci. Tech. B*, 38 (5): 433-46, 8 figs. (incl. 2 geol. maps).

In the Rangitikei-Manawatu district marine sediments of the Hawera Series, of late Pleistocene age (the Pleistocene epoch is here regarded as including the Recent age) have been folded to form several strikingly youthful asymmetrical anticlines. Extensive remnants of the original surface of the coastal plain that has been deformed are preserved as undissected interfluvial areas. The flanks of all the anticlines are drained by secondary consequent streams, which in several instances feed synclinal primary consequents. It is tentatively suggested that the crest of the Mt Stewart-Halcombe anticline has been raised to a height of 560 ft above sea level in about 20,000 years at an average rate of approximately 1 ft in 36 years. It seems that tectonic activity is still in progress, and the anticlines are therefore interpreted as live folds, and as young as any described in other parts of the world.

The present topography closely reflects the sub-surface structure as determined by geophysical surveys. The deformation of the coastal plain, which commenced in the late Pleistocene, appears to be related to faulting in the greywacke basement, and the anticlines described are termed "draped folds".

The anticlines, all of which have prominent geomorphic expression in the landscape, are named as follows: Marton, Mt Stewart-Halcombe, Feilding, Oroua, Pohangina, and Levin. The Mt Stewart-Halcombe anticline is a typical example: length 7 miles; even crest, trending north-south, rises northward from 442 to 560 ft above sea level; surface of west flank slopes west at 2° ; surface of east flank slopes east at 6° ; slope of surface on both flanks parallels the observed dip of underlying beds; radial drainage patterns emphasise closure at the north and south ends. (Author's abstract modified.)

- 57/113—TE PUNGA, M. T. Periglaciation in Southern England. *Tijdschrift van het Koninklijk Nederlandsch Aardrijkskundig Genootschap*, 74 (3): 400–12, 2 pls., 5 figs.

The following relict periglacial features of Southern England are discussed: fossil ice wedges, involutions, "crude" honeycomb structure, frozen ground in pipes, altiplanation terraces, solifluxion deposits, block fields and block streams, joints opened by frost action, ventifacts, and loess. Two-storied cliffs, dry valleys, large-scale superficial structures, and the general character of the relict periglacial landscape are also considered briefly. In Southern England the last periglacial episode ended less than 10,000 years ago. (Author's abstract.)

THOMPSON, G. E. K.: See 57/5.

TOLLEY, W. P.: See 57/75.

- 57/114—TOWNROW, J. A.: On *Dicroidium*, probably a Pteridospermous Leaf, and other Leaves now Removed from this Genus. *Trans. geol. Soc. South Africa* 60: 21–60, pls. 2–3.

Redefines the genus *Dicroidium* Gothan, describes four species and synonymises the New Zealand Triassic-Jurassic *Thinnfeldia odontopteroides* (Morris) and *T. lancifolia* (Morris) described by Arber (1917) under *D. odontopteroides* (Morris) Gothan, the type of the genus. *T. feistmanteli* ? (Gothan), recorded by Arber from the Jurassic of Southland – South Otago, is synonymised with *D. feistmanteli* (Johnston) Gothan. The age and geographical range of *Dicroidium* are discussed. (I.G.S.)

- 57/115—TYLER, C.: Some Chemical, Physical and Structural Properties of Moa Egg Shells. *J. polynes. Soc.*, 66 (1): 110–30, 6 figs.

An account of work at the University of Reading, in which six samples of moa egg shell have been examined by methods that included physical measurements, chemical analysis, and a study of the structure by the use of plastics. (D.R.G.)

- 57/116—VELLA, P.: Studies in New Zealand Foraminifera. *N.Z. geol. Surv. Pal. Bull.* 28. 64 pp. 9 pls. 3 figs.

Part I: Foraminifera from Cook Strait (pp. 5–41).

One hundred and eighty-nine species of Foraminifera are recorded from dredgings from Cook Strait, mostly taken by H.M.N.Z.S. *Lachlan*. Their distribution does not seem to be influenced by the grade of the sediments. Most species, especially the more common ones, are present through a large range of depths. This wide distribution is evidently due to transport and redeposition of the shells by vigorous bottom currents that scour the seabed of Cook Strait.

There are very puzzling gaps in the distribution of *Turborotalia inflata* d'Orb. and *Orbulina universa* d'Orb.

Microfaunas restricted to a few species were found in Marlborough Sounds.

Reworked microfossils were found in some dredgings.

The considerable difference between early Pleistocene and Recent faunas is emphasised. Of the species recognised in Cook Strait 31 are probably post-Castlecliffian invaders.

New genera proposed are: *Parvigenerina* (Textulariidae), *Siphonaperta* and *Quinquinella* (Miliolidae). *Lachlanella* is proposed as a new subgenus of *Quinqueloculina*. Forty-six new species, two new subspecies, and one new name are proposed and described.

Part II: Upper Miocene to Recent Species of the Genus *Notorotalia* (pp. 42-58).

Fifteen species and subspecies of *Notorotalia* are described: *N. clathrata* (Brady), *N. zelandica zelandica* Finlay, *N. taranakia* n. sp., *N. pristina* n. sp., *N. burupiensis* n. sp., *N. depressa* n. sp., *N. pliozea* n. sp., *N. olsoni* n. sp., *N. kingmai* n. sp., *N. finlayi* n. sp., *N. inornata* n. sp., *N. zelandica mangaoparia* n. subsp., *N. zelandica rotunda* n. subsp., *N. aucklandica* n. sp., *N. profunda* n. sp.

Zelandica, *spinosa*, and *profunda* species groups are proposed. The phylogeny of the *zelandica* and *profunda* groups is discussed briefly.

The stratigraphic ranges of the species described are fully dealt with. (Author's abstracts.)

57/117—WATERHOUSE, J. B.: Rock Fans in South-East Wellington. *Trans. roy. Soc. N.Z.* 85 (1): 101-11, 2 pls. 3 figs.

Large rock fans with a veneer of alluvium exist on the eastern flank of the southern Haurangi Mountains. These have been carved by small, heavily-loaded streams in relatively unresistant Cretaceous and Tertiary beds. Following the formation of the fans the streams became incised, and new rock fans were carved into the older ones. This process has recurred several times, and now up to five rock terraces border the lowest rock fan. Alluvium to a depth of more than 40 ft on the lowest rock fan is tentatively correlated with the rise of sea level following the Wisconsin (Würm) Glaciation. It is suggested that most of the lateral planation to form the rock fans occurred during the glacial episodes of the Pleistocene, and was followed by aggradation on the lower slopes of the fans in the early part of the warm periods with the rise in sea level. Later, dissection occurred during the later part of each warm and early part of the next cold period. Tectonic uplift has also been involved (Author's abstract slightly modified.)

57/118—WATERHOUSE, J. B.; BRADLEY, J.: Redeposition and Slumping in the Cretaceous-Tertiary Strata of S.E. Wellington. *Trans. roy. Soc. N.Z.* 84 (3): 519-48, 5 pls.

The stratigraphy of lower Tertiary sediments in the Opouawa area is described, and conditions of deposition are considered in relation to the hypothesis of slumping and redeposition. Northward facies change of the Amuri Limestone into redeposited argillites is discussed, and it is concluded that the limestone also is, at least in part, of redeposited origin. Consideration is given to the effects of contemporaneous growth and submarine erosion of folds, and slump structures are regarded as tectonic erosional phenomena and as indices of orogenic movement. Slump structures, including exceptional sedimentary dykes, are described, and their modes of formation are interpreted in terms of bedding-plane slip. (Author's abstract.)

57/119—WEBSTER, K. A.: Jade or Greenstone as a Term. *J. polynes. Soc.* 66 (2): 210-1.

A reply to Adkin (1956: *J. polynes. Soc.* 65: 176-7, abstract 56/2) arguing that jade and nephrite are synonymous. The use of the term 'greenstone' is deprecated, and 'nephrite' (or 'jade') and 'bowenite' are preferred. See also 57/97. (D.R.G.)

57/120—WHITE, D. E.: Thermal Waters of Volcanic Origin. *Bull. geol. Soc. Amer.*, 68 (12): 1637-58.

Discusses the origin of thermal waters using many New Zealand examples from publications of Grange and Wilson. (D.R.G.)

- 57/121—WILLETT, R. W.: The Work of the Geological Survey. *N.Z. Coal*, 1 (4): 6-7.

An account of work by the N.Z. Geological Survey in New Zealand coalfields. Bulletins have been issued on the Greymouth (1913 and 1952), Buller-Mokihinui (1915), Reefton (1917), Mokau (1923), Waikato (1926), and Kaitangata (1939) fields. Bulletins on Ohau and a resurvey of Kaitangata are due for early publication. Work is in progress in the Waikato, and may be needed in future in North Taranaki. (B.W.C.)

- 57/122—WILLIAMS, G. J.: "New Mineral Discoveries in the Nelson Province": Cawthron Memorial Lecture 32. 29 pp., 5 pls., 3 figs. Stiles, Nelson.

After a brief history of mineral discoveries in the Nelson district, the discovery of uranium in the Buller district and the possibilities of mining uranium ore in New Zealand are described. The distribution of the host formation, the Hawk Crag Breccia, and its correlatives is shown on maps. Credit is given to Messrs Cassin and Jacobsen who made the first discovery of uranium ore. The discovery for the first time in Nelson of scheelite and vermiculite by Mr C. J. Sixtus of Canaan is also announced. Nelson is described as, apart from oil possibilities, the most promising mineral area in New Zealand. (B.W.C.)

- 57/123—WILSON, J. T.: Origin of the Earth's Crust. *Nature*, 179 (4553): 228-30.

Suggests that the material of the crust is derived from lavas erupted on to an original surface that now constitutes the Mohorovicic discontinuity. The disturbance to the earth's principal moments of inertia by the emission of lavas, sedimentation, sudden uplift, and metamorphism may have caused polar wanderings. Shearing along existing belts of weakness may explain large transcurrent faults like the San Andreas of California and the Alpine Fault of New Zealand, which appear to have been superimposed on pre-existing mountain structures in Mesozoic or Tertiary time. As the faults show rapid movement (about an inch a year), they must be of fairly recent origin. (B.N.T.)

- 57/124—WOOD, B. L.: Geological Structure (of the Darran Mountains). pp. 108-9 in *The Mountains of New Zealand. Part 4 - The Darran Region. N.Z. alpine J.*, 17 (44): 107-44.

The predominant rock is a coarse diorite or dioritic gneiss, with rare veins of pegmatite. The diorites are bounded to the east by the Hollyford-Eglinton Fault, and along the coast to the west by the Alpine Fault. The present topography is the result of strong glacial erosion of an uplifted land surface of low relief. Mention is made of numerous cirque lakes and a large moraine damming Lake Adelaide. (B.W.C.)

- 57/125—WOOLNOUGH, W. G.; BENSON, W. N.: Graphical Determination of the Dip in Deformed and Cleared Sedimentary Rocks. *J. Geol.* 65 (4): 428-33, 4 figs.

A graphical construction is described for determining the attitude of stratification planes that make a measurable trace on two non-parallel and, in general, non-vertical faces. (Authors' abstract.) (See also discussion by D. J. Fisher, *ibid.*, 66 (1): 100; 1958.)

- 57/126—WRIGHT, C. W.: Cretaceous Ammonites from New Zealand. *Trans. roy. Soc. N.Z.*, 84 (4): 805-9, 2 pls.

New ammonite material from the Clarence Valley and Hawke's Bay areas has been classified under the following genera: *Phyllopachyceras*, *Gaudryceras*, *Anagaudryceras*, *Puzosia*, *Pachydesmoceras*, *Kitchinites*?, *Diplomoceras*, and *Grossouvreites*. Other fragments are identified with *Hyphantoceras* cf. *reussianum* (d'Orbigny) and *Pseudoxylloceras* sp. aff. *quadrinodosum* (Jimbo). *Otoscaphtes awanuiensis* n. sp. is described from the Clarence Series of Port Awanui, near East Cape. A new genus, *Wellmanites* (Kossmaticeratidae) is proposed for *W. zelandicus* n. sp. from the Upper Clarence Series, probably Cenomanian, of Gentle Annie Stream, Eketahuna district. (Author's abstract slightly modified.)